



UNDERSTANDING PREDATION

A review bringing together natural science and local knowledge of recent wild bird population changes and their drivers in Scotland



**UNIVERSITY OF
STIRLING**

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CONTENTS

CONTENTS.....	2
INTRODUCTION	9
ACKNOWLEDGEMENTS.....	11
EXECUTIVE SUMMARY	14
Overall aims	14
Study approach	14
Participants holding local and scientific knowledge	15
Common ground on conservation evidence, drivers of population change and conservation- management techniques	15
Areas of divergent understanding and possible reasons.....	16
Synthesis of knowledge bases	17
Future collaboration and work	18
Report structure.....	19
UNDERSTANDING PREDATION – SUMMARY REPORT	20
1. INTRODUCTION	20
Background	20
Aims and objectives of the project	21
Focal species	22
Structure of the reporting.....	23
2. REVIEWING METHODS	23
2.1 Social science methods	23
Questionnaire design	23
Classifying stakeholder groups.....	24
Workshop and seminar programmes	24
Comparison of knowledge	24
2.2 Natural science methods	24
Population trends of predators and wild bird prey	24
Review of natural science literature	25
3. HOW DO STAKEHOLDERS GAIN AND USE KNOWLEDGE?	25
4. POPULATION TRENDS OF WILD BIRDS AND THEIR PREDATORS IN SCOTLAND	26
4.1 Natural science review of population change for terrestrial wild birds and their predators in Scotland	26

Population trends of predatory mammals.....	27
Population trends of predatory birds	27
4.2 Stakeholder perceptions of population trends for wild birds and their predators	28
4.3 Population trends of wild birds and their predators in Scotland – comparison of stakeholder knowledge and natural science findings.....	28
5. DRIVERS OF POPULATION CHANGE OF WILD BIRDS, INCLUDING THE ROLE OF PREDATION	31
5.1 Natural science review of drivers of population change for wild birds and their predators.....	31
Difficulties of assessing the relative importance of population drivers	31
FOCAL SPECIES – BLACK GROUSE.....	31
FOCAL SPECIES - CURLEW	32
FOCAL SPECIES – GOLDEN PLOVER	33
FOCAL SPECIES – GREY PARTRIDGE	34
FOCAL SPECIES - LAPWING.....	34
FOCAL SPECIES - OYSTERCATCHER.....	35
UPLAND GAMEBIRDS	36
UPLAND WADERS.....	36
OTHER UPLAND BIRDS	36
LOWLAND GAMEBIRDS AND WILDFOWL	36
LOWLAND WADERS	37
OTHER LOWLAND BIRDS	37
RAPTORS AND CORVIDS.....	37
5.2 Stakeholder understanding of drivers of population change for wild birds.....	37
Environmental and human drivers of population change	37
Predator species perceived to drive population change	38
5.3 Drivers of population change for wild birds in Scotland and the role of predation – comparison of stakeholder knowledge and natural science findings	41
6. CONSERVATION-MANAGEMENT OPTIONS.....	44
6.1 Natural science review of the evidence for the success, or otherwise, of conservation-management options.....	44
PREDATION MANAGEMENT.....	44
HABITAT AND FOOD SUPPLY.....	47
COMBINED MANAGEMENT	48
6.2 Stakeholder definitions of ‘healthy populations’	49
6.3 Stakeholder understanding of effectiveness of management options	50

6.4 Effectiveness of management options – comparison of natural science findings and stakeholder knowledge.....	51
7. FUTURE ACTIONS AND PRIORITY KNOWLEDGE GAPS.....	53
7.1 Future collaborative actions	53
7.2 Priority knowledge gaps.....	58
8. DISCUSSION	59
8.1 Novelty of project approach	59
8.2 Commonalities and differences in understanding between stakeholder groups and the scientific literature	60
8.3 Challenges, constraints and achievements.....	61
8.4 Conclusions and the way forward?.....	63
UNDERSTANDING PREDATION – SUPPLEMENTARY MATERIAL.....	65
CONTENTS.....	65
1. HOW TO USE THIS SECTION.....	70
2. REVIEWING METHODS	71
2.1 Natural science research methods	71
2.1.1 ANALYSIS OF POPULATION TRENDS.....	71
2.1.2 OTHER PROJECT-SPECIFIC ANALYSES.....	77
2.1.3 FORMAL LITERATURE-SEARCHING METHODS	78
2.1.4 OTHER SOURCES OF INFORMATION FOR THE REVIEW	83
2.1.5 FORMAL SYSTEMATIC EVALUATION OF LITERATURE	84
2.2 Social science research methods	85
2.2.1 SAMPLING STRATEGY.....	86
2.2.2 QUESTIONNAIRE DESIGN	86
2.2.3 WORKSHOP PROGRAMME.....	87
2.2.4 SEMINAR PROGRAMME.....	87
2.3 Analyses	88
2.3.1 QUALITATIVE ANALYSIS - CODING	88
2.3.2 CLASSIFYING STAKEHOLDER GROUPS.....	88
2.3.3 COMPARISON ON KNOWLEDGE	90
2.3.4 UNCOVERING COMMONALITIES AND DIFFERENCES BETWEEN STAKEHOLDER KNOWLEDGE AND NATURAL SCIENCE REVIEWING	90
2.3.5 STATISTICAL ANALYSES	91
2.3.6 QUESTIONNAIRE PARTICIPANTS – CHARACTERISTICS OF THE SAMPLE	91
3. HOW DO STAKEHOLDERS GAIN AND USE KNOWLEDGE?	93

3.1 Ways in which stakeholders gain information.....	93
3.2 Use of knowledge to make assessments about drivers of population change	98
4. POPULATION TRENDS OF WILD BIRDS AND THEIR PREDATORS IN SCOTLAND	99
4.1 Review of population trends for mammal predators of wild birds	99
EUROPEAN HEDGEHOG	99
RED SQUIRREL	100
GREY SQUIRREL	101
COMMON RAT	102
SHIP RAT.....	102
RED FOX	103
PINE MARTEN.....	104
STOAT.....	104
WEASEL	105
POLECAT.....	105
FERAL FERRET.....	106
AMERICAN MINK.....	106
BADGER.....	107
OTTER.....	108
WILDCAT	108
FERAL / DOMESTIC CAT.....	109
4.1 Review of population trends for raptor predators of wild birds	110
RED KITE	110
WHITE-TAILED EAGLE.....	113
HEN HARRIER	115
GOSHAWK	118
SPARROWHAWK	120
COMMON BUZZARD	122
GOLDEN EAGLE	125
KESTREL.....	128
MERLIN.....	131
PEREGRINE	133
TAWNY OWL	138
SHORT-EARED OWL.....	140
4.3 Review of population trends for corvid predators of wild birds.....	142

MAGPIE	142
JAY	145
JACKDAW	147
CARRION & HOODED CROWS	150
RAVEN	153
4.4 Review of population trends for skua and gull predators of wild birds	156
ARCTIC SKUA	156
GREAT SKUA	158
BLACK-HEADED GULL	160
COMMON GULL	162
LESSER BLACK-BACKED GULL	164
HERRING GULL	166
GREAT BLACK-BACKED GULL	168
4.2 Review of population trends for wild bird prey: focal species	170
BLACK GROUSE	170
CURLEW	173
GOLDEN PLOVER	176
GREY PARTRIDGE	179
LAPWING	182
OYSTERCATCHER	185
4.3 Review of population trends for wild bird prey - other breeding wild birds	188
Changes in Scottish breeding bird populations since 1988-91	188
Changes in Scottish breeding gamebird populations since 1988-91	188
Changes in Scottish breeding wader populations since 1988-91	189
Changes in Scottish breeding bird of prey populations since 1988-91	189
Changes in Scottish breeding waterbird populations since 1988-91	189
Changes in Scottish breeding songbird and near passerine populations since 1988-91	189
Changes in Scottish breeding bird predator populations since 1988-91	190
Changes in Scottish breeding populations of birds on General Licences 1-3 since 1988-91	190
Comparison of changes between upland and lowland land types since 1988-91	190
Changes by Natural Heritage Zone of Scotland since 1988-91	190
4.4 Stakeholder perceptions of population trends for wild birds and their predators	203
4.4.1 Questionnaire results	203
4.4.2 Workshop results	203

4.5 Population trends of wild birds and their predators in Scotland – comparison of stakeholder knowledge and natural science findings.....	205
4.5.1 Questionnaire results.....	205
4.5.2 Workshop results	205
4.5.3 Seminar results	206
5. DRIVERS OF POPULATION CHANGE OF WILD BIRDS AND THEIR PREDATORS, INCLUDING THE ROLE OF PREDATION	208
5.1 Natural science review of drivers of population change for wild birds and their predators....	208
PREDATION	208
OTHER DRIVERS OF CHANGE	212
FOCAL SPECIES – BLACK GROUSE.....	218
FOCAL SPECIES - GREY PARTRIDGE	223
FOCAL SPECIES - LAPWING.....	226
FOCAL SPECIES - GOLDEN PLOVER.....	232
FOCAL SPECIES - OYSTERCATCHER.....	235
FOCAL SPECIES - CURLEW	237
UPLAND GAMEBIRDS	240
UPLAND WADERS.....	245
OTHER UPLAND BIRDS	246
LOWLAND GAMEBIRDS AND WILDFOWL	247
LOWLAND WADERS	248
OTHER LOWLAND BIRDS	250
RAPTORS AND CORVIDS.....	254
5.2 Stakeholder understanding of population drivers of wild birds and their predators.....	256
5.2.1 Environmental and human drivers of population change	256
5.2.2 Predator species perceived to drive population change (focal species)	268
6. CONSERVATION-MANAGEMENT OPTIONS.....	275
6.1 Natural science review of conservation-management options.....	275
PREDATOR MANAGEMENT	275
HABITAT AND FOOD SUPPLY.....	285
COMBINED MANAGEMENT	289
6.2 Stakeholder definitions of ‘healthy’ populations.....	293
6.2.1 Stakeholder Knowledge – definitions of ‘healthy’ populations.....	293
6.3 Stakeholder understanding of effectiveness of management options	295
6.3.1 Questionnaire results.....	295

6.3.2 Workshop results	300
6.3.3 Seminar results	311
6.4 Effectiveness of management options – comparison of natural science findings and stakeholder knowledge.....	311
6.4.1 Questionnaire results.....	311
6.4.2 Seminar results	314
7. GAPS IN UNDERSTANDING & FUTURE PRIORITIES.....	315
7.1 Knowledge gaps	315
7.2 Future collaborative actions	320
8. DISCUSSION	333
9. LITERATURE CITED.....	335
APPENDICES.....	336
Appendix 1: Questionnaire and workshop participants’ organisational affiliation	337
Appendix 2: Online questionnaire	340
Appendix 3: Main topics of the online questionnaire	341
Appendix 4: Understanding Predation workshop timetable and participants.....	343
Appendix 5: Understanding Predation workshop guide.....	344
Appendix 6: Review seminar guides	347
Appendix 7: ‘Other’ most important forms of information.....	350
Appendix 8: Local and Scientific Knowledge group respondents’ organisational associations.....	351
Appendix 9: Questionnaire respondents’ socio-demographic information	352
Appendix 10: Organisational affiliation of questionnaire respondents.....	353
Appendix 11: Breeding distribution change at NHZ scale	355
Appendix 12: Definitions of ‘healthy’ populations of predators and prey	380
Appendix S1: Conservation status	382
Appendix S2: National population change.....	382
Appendix S3: NHZ abundance change	382
Appendix S4: Abundance change by land type.....	382

INTRODUCTION

Lord Lindsay, Chairman of Scotland's Moorland Forum



Predation is a natural process. Yet it often causes controversy and divides opinion, with the scientific understanding of different predator-prey interactions not being recognised by those who work on the land, whose local understanding derives from what they see on a daily basis, and vice versa.

To identify better solutions to longstanding problems, it is clear that we must first bring together the differing views about predation. A polarised and adversarial approach to our understanding of predation only serves to perpetuate the problems, including those relating to the persecution of raptors. This further exacerbates the severe population declines of the species that we are seeking to protect and enhance.

Against this background, Paul Wheelhouse, MSP, while he was Minister for Environment and Climate Change, made it clear that the status quo was unacceptable and that new solutions must be found. This led to the Moorland Forum being asked by the Minister to deliver a project that would enable a fresh approach to be taken to issues surrounding predation.

Our starting point would be the updating of what has become known as 'The Predatory Birds Report', which was commissioned by the Forum and published in 2005. At the same time, it was agreed that the updated information provided by the science should be compared with the local knowledge held by those who have a direct connection with the land. This novel approach evolved into the Understanding Predation project, which would aim to establish baseline information about predation that all stakeholders could broadly agree.

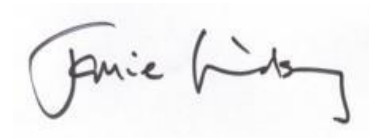
In view of the novelty and sensitivities, the multi-stakeholder Planning Group worked with SNH over a considerable period to finalise the design of the project plan before the project itself got underway in December 2014. The timescale for completing the work and presenting the findings has been challenging. Nonetheless, I believe that the agreed baseline it sought has been achieved, and that it provides a fresh starting-point for considering future solutions.

Importantly, the report recognises that the need to identify and progress new solutions is urgent. Furthermore, it is clear that the project has inspired significant momentum and a desire for continuing collaboration. This therefore is an undoubted opportunity to harness that momentum and collaborative spirit to tackle issues that have long needed to be more effectively addressed. It is an opportunity that we must not waste.

Beyond this headline are two further notable achievements, which in themselves are significant for the future. First, the Moorland Forum has demonstrated that, with the support of other specialists, it has been possible to bring a diverse range of interest groups together to discuss often divisive topics in an intelligent, considered and constructive fashion. Second, the novel approach adopted by the project has shown that there is a high level of agreement between the local knowledge of those who work on the land day-in and day-out, and the evidence derived from scientific surveys. This will surprise many people.

I believe that this Report is a turning-point in how the conflicts that build up around predation can in future be better understood and addressed. It has established a new starting-point and roadmap going forwards for resolving those predator-prey conflicts that cause concern.

I commend the findings of this project to the Scottish Government.

A handwritten signature in black ink, appearing to read 'Lord Lindsay', is centered on the page. The signature is fluid and cursive, with a large initial 'L' and a long, sweeping underline.

Lord Lindsay

ACKNOWLEDGEMENTS

I would like to acknowledge the vision of Paul Wheelhouse, MSP in starting this process, and the unflagging backing that we have received from his ministerial successor, Dr Aileen MacLeod, MSP. Their high-level endorsement for the project has been instrumental in giving it both momentum and direction.

The support and advice from Scottish Natural Heritage, notably Roger Burton and Des Thompson, have been vital, as has been their determination throughout to see the project vision become a hard reality. We also thank Jess Findlay for her careful administration of the project and Ben Ross for additional advice.

A large team of people has been responsible for delivering this project. The main groups are listed below and they have all contributed greatly to the project. Simon Thorp (The Heather Trust) managed the project tirelessly, with the assistance of Anne Stoddart, on behalf of the Moorland Forum.

The Steering Group has provided essential support and guidance for the members of the Research Group, who have toiled to assemble all the information and collate it into this report. Special mention must be made of Professor Steve Redpath (University of Aberdeen) and Dr Chris Wernham (British Trust for Ornithology) who not only oversaw the project but also had a large input to the development of the project plan. On their behalf, I would also like to thank the other members of BTO staff who assisted with the project (John Calladine, Anne Cotton, Simon Gillings, Ali Johnstone, Blaise Martay and Carole Showell), and Catriona Mackison for her assistance with workshops and seminar note-taking.

I am indebted to the Review Panel who provided their external and independent views to me direct about the project and the report. I am also indebted to the three external reviewers, who had not had direct involvement with the project. They were engaged at short notice to provide some additional, independent input from across the Forum's spectrum of member organisations. I would like to thank them for responding to the call and for meeting the tight deadline.

Of equal, and perhaps greater, importance to the project has been the input from the many 'stakeholders'. They have contributed to the project in many ways: adding posts to the project's blog; completing questionnaires; attending the workshops; supplying additional literature for review; attending the project review seminars; completing the final survey; and, above all, taking part in the discussion. This project has not been delivered by a few computer slaves; it has harnessed the knowledge, experience and perspectives of a very large number of people. They have given their time freely to tell us what they think.

Lord Lindsay on behalf of the Project Team

Steering Group

Name	Surname		Organisation
Lord	Lindsay		Chairman
Simon	Thorp	*	Project Manager
Tim	Baynes	*	Scottish Land & Estates
Will	Boyd-Wallis		Cairngorms National Park Authority
Hugh	Dignon		Scottish Government
Jessica	Findlay		Scottish Natural Heritage
Ronnie	Kippen	*	Scottish Gamekeepers Association
Davy	McCracken	*	Scotland's Rural College
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Adam	Smith	*	Game & Wildlife Conservation Trust
Des	Thompson		Scottish Natural Heritage

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Name	Surname		Organisation
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Kirsty	Park		University of Stirling
Steve	Redpath	*	University of Aberdeen
Chris	Wernham	*	British Trust for Ornithology
Mark	Wilson		British Trust for Ornithology
Juliette	Young	*	Centre for Ecology & Hydrology

Review Panel

Name	Surname		Organisation
Dr Bob	McIntosh		Retired FCS
Prof Ian	Newton		Retired
Prof Mark	Reed		Birmingham City University
Prof Paul	Sillitoe		University of Durham

External Reviewers

Name	Surname		Organisation
Dr Justin	Irvine		James Hutton Institute
Dr Jonathan	Reynolds		GWCT
Dr Staffan	Roos	*	RSPB

The Stakeholders

Contributors		Numbers
Blog viewers		8,604
Blog commenters		73
Questionnaire completers		400
Workshop attendees		62
Review Seminar attendees		109
Final Survey Completers		40

* = Member of the Planning Group for the Project

EXECUTIVE SUMMARY

Overall aims

1. The roles that predators play within ecosystems and their management are of considerable interest to stakeholders across Scotland. Divergent views about the importance of predator influences on populations of ground-nesting birds, and the potential management of these influences, can raise strong emotions amongst stakeholders.

2. Scotland's Moorland Forum recognised that an independent and impartial assessment of the evidence for predator impacts, and for the effectiveness of a range of conservation-management strategies, would benefit decision-making in this challenging area. The Forum recognised that previous assessments based on evidence from the ecological scientific literature had not been widely accepted, and had not led to conciliatory or shared actions. The Forum therefore committed to a more collaborative knowledge gathering study, drawing on both scientific literature and 'local knowledge' held by a wide range of stakeholders.

3. This project was commissioned by the Scottish Government, funded by Scottish Natural Heritage, managed by Scotland's Moorland Forum and led by an independent and strictly impartial Research Group drawn from the British Trust for Ornithology (Scotland), Centre for Ecology and Hydrology, and Universities of Aberdeen and Stirling.

4. The objectives of the study were to: i) review the published scientific evidence of predator-prey interactions where relevant to the Scottish context, focusing on species trends, drivers of change in populations, the impact of predators on their prey and the existing evidence for the success of alternative management options; ii) establish stakeholders' knowledge and management experience of predator-prey interactions, examining the arguments and evidence supporting these; and iii) identify and explore the reasons for uncertainties and gaps in comparisons between the science and stakeholder knowledge.

Study approach

5. Moorland Forum members agreed that the project should be founded on a shared aspiration to establish and maintain 'balanced' and 'healthy' populations of all wild birds in Scotland, and their predators. They chose to focus a large part of the project around six focal ground-nesting wild birds (four breeding wader and two native gamebird species). For each of these, there were widely held concerns over recent population declines and a shared desire to find ways of reversing declines.

6. The project collected knowledge in a rigorous and equitable manner both from the ecological scientific literature (via a systematic reviewing process) and from a broad range of local stakeholders (via questionnaires, workshops and seminars). This novel approach aimed to assess the extent to which the two forms of knowledge aligned. Commonalities help to build consensus, whilst differences highlight knowledge gaps or areas of contention that may be barriers to progress.

7. The project sought to compare knowledge regarding: i) the recent population changes of six prey species (Black Grouse, Curlew, Golden Plover, Grey Partridge, Lapwing and Oystercatcher) and some of their more common predators (Buzzard, Carrion/Hooded Crow, Raven Red Fox); ii) evidence for

the factors driving these changes (including predation); and iii) evidence for the success, or otherwise, of various types of conservation management for the prey species.

8. Inclusive projects that fully involve stakeholders in all stages from inception to delivery can be time intensive to implement well. The current project had to be delivered within 12 months, and this placed some constraints on the approach that could be taken and the order in which components had to be delivered. These challenges are explained and their implications explored.

Participants holding local and scientific knowledge

9. The study draws on the knowledge of more than 400 stakeholders, who responded to a project questionnaire; more than 60 of these project participants also attended a project workshop. Whilst these participants were not selected using a strict sampling strategy, they represented more than 70 different organisations and thus a broad range of the relevant interests.

10. Knowledge relates to our understanding of the world around us and how we interpret our experiences and thoughts. Some project participants relied to a large extent on 'local knowledge'; they valued first-hand experiences and peer knowledge because both were considered to provide unparalleled breadth and depth of understanding, with observations regarded as reliable and unbiased. Some participants relied to a large extent on 'scientific knowledge'; they considered that decision-making should be unbiased and independent, and best derived through independent, peer-reviewed, academically robust studies. Many participants relied on both local and scientific knowledge to varying degrees, and both forms were criticised and mistrusted when perceived as subjective or partial.

Common ground on conservation evidence, drivers of population change and conservation-management techniques

11. The project confirmed that all six prey species have shown widespread declines across Scotland since the 1960s, with strong support for this conclusion from both the natural science review of ecological survey data and project participants.

12. Project participants strongly agreed about the immediate need to conserve ground-nesting bird species, including the six focal species, and the urgency of action needed.

13. Overall, there was consensus between participants' knowledge and the ecological survey data about changes over the last 25 years in the abundance of three of four common predators considered. Both knowledge sources identified wide-spread increases in the abundance of Buzzards and Ravens. For Red Fox, participants considered the population to have shown a small increase, consistent with the best available game bag data (which suggested a long-term increase followed by some decline since the mid-1990s).

14. There was considerable agreement between the ecological scientific literature and knowledge about the ranked order of factors influencing population change of the six wild bird prey species. Both predation and habitat were ranked highly by stakeholders and the scientific literature, and there was agreement that these two processes often interact.

15. Participants agreed that Carrion/Hooded Crow and Red Fox are significant predators of the six prey species and a range of other bird and mammal species. There were also broad similarities between

the stakeholder knowledge groups and the scientific literature in the ranking of predator species in terms of their impact on the prey species.

16. Participants also agreed that suitable habitat (resulting from appropriate habitat management practices) is vital for ground-nesting birds to prosper, and broadly supported measures to improve habitat quality where appropriate.

17. Of 49 relevant scientific studies, around half considered the effectiveness of lethal predator control and half considered habitat management; few considered other forms of non-lethal predator management. Similarly high proportions (greater than 80%) of the studies that considered lethal predator control or habitat management, found them to be effective at least some of the time. Similarly, there is greater practical experience of the effectiveness of lethal predator control and habitat management among stakeholders than other forms of predator management. Most local and scientific knowledge holders considered predator control and habitat management to be effective at least sometimes for achieving the goal of healthy populations of focal prey species and their predators.

18. Overall, participants agreed that: i) factors influencing population change can interact to stimulate predator and prey population changes; ii) measuring the impacts of any single driver in isolation can be problematic; and iii) implementing a combination of techniques is therefore more likely to be effective in this context than use of any single technique.

Areas of divergent understanding and possible reasons

19. Participants considered that crow population change was more positive than the ecological survey findings. Of the many possible reasons for this difference, the most probable related to the geographical scale of surveys, the survey design and its original purpose (resulting in a lack of information on changes in numbers of non-breeding birds outside the breeding season).

20. Participants with local knowledge considered that Buzzard, Carrion/Hooded Crow, Raven and Red Fox had increased significantly more than did those holding scientific knowledge. Local knowledge holders considered the decline in Golden Plover to be greater than the evidence from ecological surveys, while scientific knowledge holders considered the declines in Grey Partridge and Oystercatcher to be less severe than surveys suggested (probably due to their varying local experiences).

21. Participants agreed less on the extent to which Buzzard and Raven are significant predators of the six prey species: holders of scientific knowledge generally considered them of lower importance than did holders of local knowledge. In total, 27 species were identified by stakeholders as important predators, including: Stoat; Weasel; American Mink; Badger; and Pine Marten. Gulls and Sparrowhawk received frequent mentions as predatory birds. These species were sometimes considered more important than some of the four common focal predators. Further scientific studies would be needed to quantify the scale, intensity and management of the impacts for many of these predatory species however.

22. Those holding local knowledge considered human disturbance to have had an important impact on the focal ground-nesting prey species over the last 25 years (based on personal observations). Scientific knowledge holders prioritised disturbance less so, and relevant scientific studies are lacking.

23. Those holding local and scientific knowledge agreed about the relative impact of different drivers on populations of Black Grouse, Golden Plover and Lapwing but there was less agreement about Curlew, Grey Partridge and Oystercatcher populations.

24. Whilst stakeholders could agree a common goal *“to establish and maintain balanced and healthy populations of all wild birds in Scotland, and their predators”*, the definitions of “healthy populations” (in terms of target range, density and productivity) varied between knowledge groups according to associated conservation-management objectives. The most common aim amongst both knowledge groups was to achieve an overall balance and/or sustainability of both predator and prey populations, allowing for fluctuating populations but relative stability over the longer term.

25. Project participants differed in their views on the most appropriate means of conserving the six ground-nesting bird species according to particular conservation-management objectives. Local knowledge holders, who saw predators as the most immediate threat, favoured direct lethal predator control, whereas those scientific knowledge holders who viewed human activities as the most important threat favoured habitat management and improving habitat quality across the landscape as their long-term goal.

26. Lethal predator control was rated ‘generally effective’ more often than other conservation-management techniques, particularly among those holding local knowledge, probably due to higher levels of understanding of, and experience with, this technique compared with other techniques. Participants considered that: i) predators are more visible than other potential drivers; ii) many predator species are perceived to have increased in abundance; and iii) predator control is observed to have an immediate impact which is beneficial in this context.

27. Divergence of views between local and scientific knowledge participants about the need for increased predator control measures centred on: i) the desire among some stakeholders for populations of gamebirds large enough to be regularly and sustainably shot (perceived as artificially high by other stakeholders); and ii) a lack of understanding of the drivers of illegal activities. Other differences in consensus centred on the extent to which wide-scale coordinated effort was required, aspects of species licensing, and public and political support (or lack of this) for certain measures.

28. Differences in understanding between local and scientific knowledge participants about whether habitat management is the most appropriate conservation-management strategy may have been influenced by: i) an understanding that the effects of habitat management may be subtle and take longer to achieve; ii) the efficacy of habitat management being more context-dependent than that of predator control; iii) habitat management possibly requiring changes in some land-use practices and therefore more widespread landholder cooperation than predator control; iv) the highly managed, fragmented nature of Scotland’s landscape making it difficult to achieve large-scale continuous habitats identified as necessary by some; and v) improving habitat quality not always mitigating the cumulative impacts of increased predator population size, range and diversity.

Synthesis of knowledge bases

29. The review summarises and provides a reference source on Scotland-wide and regional population changes of predatory mammals and birds since the 1960s, and population changes of most

widespread terrestrial breeding bird prey species, using the most comprehensive information on change available (from the BTO/BirdWatch Ireland/SOC 2007-11 Bird Atlas).

30. The review provides a comprehensive synthesis for Scotland (drawn from more than 10,000 sources of ecological scientific literature) of the human-related and other environmental factors influencing population change of the six wild bird prey species. Brief syntheses of these factors are provided for other widespread terrestrial bird species. The review also considers drivers of population change of the main avian and mammalian predators of wild birds.

Future collaboration and work

31. Seminar participants identified a need to continue to build trust between stakeholders through: i) better communication and continued sharing of local and scientific knowledge; ii) increasing opportunities for networking and collaborative action; and iii) creating appropriate opportunities to jointly produce knowledge on contentious issues, and bring agreed findings to policy makers. Future work in this field should therefore focus on collaborative actions.

32. A broad range of potential future collaborative actions, suggested by participants and reviewers during the project, were grouped into three categories and scored by 35 stakeholders based on five criteria: i) opportunity for broad collaboration; ii) acceptability across stakeholders; iii) opportunity to build trust; iv) prospects of new insights and opportunity to plug knowledge gaps; and v) the level of priority placed upon them by different stakeholders. The five projects ranked highest overall included four 'Management and Ecology' category projects: 1) collection of more information on predation and predator activity relating to the six focal prey species; 2) recruitment and dispersal of Black Grouse; 3) causes of Curlew decline; and 4) the consequences of spatial pattern in predator removal. The fifth project was from the 'Attitudes and Values' category and concerned an investigation of how stakeholder attitudes and values about predation influence conservation. The highest scoring project in the 'Fostering Collaboration' category concerned the development of large-scale demonstration sites, and was ranked ninth overall.

33. Knowledge gaps in both the natural science literature and the social science understanding were documented during the project. Whilst we consider that future focus should be on collaborative actions, rather than research *per se*, future actions that serve to fill some of these knowledge gaps could be seen as delivering multiple benefits. Knowledge gaps identified include: i) size, movements and ecological impacts of non-breeding components of predator populations; ii) impacts of protected predator species; iii) ecological consequences of interactions between different predator species; iv) role of gamebird releases and other human sources of food for generalist predators; v) drivers of illegal behaviour regarding management of protected species; and vi) research into definitions of 'healthy populations' of predators and prey. The benefits of plugging these and other knowledge gaps are considered.

34. There was a strong shared desire for urgent action to address the declines of the focal species of ground-nesting wild birds rather than further research *per se*. This suggested that consideration should be given to collaborative, adaptive approaches that link trial management action(s), agreed collectively by stakeholders, to joint evaluation and stakeholder-agreed modification through time.

35. In conclusion, we consider that the project has achieved major steps forward in building consensus about the population declines of focal ground-nesting birds in Scotland, the factors driving these observed negative changes, possible remedial conservation-management techniques and suggested future collaborative actions. The collaborative working adopted during the project exemplifies an approach that, if continued effectively, should be successful in moving towards shared future solutions.

Report structure

The reporting for this project has been designed to be accessed online in web-based format. The Executive Summary is followed by a 'Summary Report', providing a synthesis of the main findings in an accessible form. The Summary Report contains direct links through to more technical and comprehensive material, with full literature citations, contained within the 'Supplementary Material'. Please note that there is a shortcut within Windows and on a Mac that allows you to return to a previous section after following one of these hyperlinks in a PDF document: this is '*Alt+left arrow*' on Windows, and '*Command+left arrow*' on a Mac.

UNDERSTANDING PREDATION – SUMMARY REPORT

1. INTRODUCTION

Background

The roles that predators play within ecosystems, and the management of predatory species, are subjects of policy relevance, as well as being of considerable current interest to stakeholders across Scotland. They are also topics that raise strong emotions. Some stakeholders are concerned about the negative impacts of predators and call for greater levels of predator control to benefit a range of prey species. In contrast, others recognise that predation is a natural process within functioning ecosystems and do not think it should be intensively managed.

Decision making in this challenging area should benefit from independent and impartial assessments of the evidence for predator impacts and for the effectiveness, or otherwise, of alternative conservation-management strategies. Scotland's Moorland Forum¹ recognised this need and, given its broad membership, was well-placed to initiate and support a truly collaborative project to carry out such an assessment. Here we report the results of such a study, commissioned by the Scottish Government Minister for the Environment, Climate Change and Land Reform, funded by Scottish Natural Heritage, and led by a strictly independent and impartial Research Group from British Trust for Ornithology (Scotland), the Centre for Ecology and Hydrology, the University of Aberdeen and the University of Stirling.

There is a wealth of published ecological literature, and a number of comprehensive reviews, on predation and ground-nesting birds from the UK and further afield, including that commissioned via Scotland's Moorland Forum and undertaken by the University of Stirling and BTO Scotland around a decade ago. This published literature comprises the findings from a wide range of studies, including some with rigorous experimental approaches addressing very specific and relevant questions. Typically, conservation-management decision making has been primarily based on this kind of assessment of scientific evidence. Yet, even when relevant science of the highest quality is available, it may be ignored or rejected by some stakeholders, and not seen as a legitimate basis on which to take management decisions. In some cases, it may be perceived as externally imposed, non-impartial or too expert-oriented and inaccessible. Moreover, the available scientific knowledge may focus on issues or questions that are not entirely relevant, it may not adequately consider local contexts, or its use in guiding decision-making may be interpreted as delaying rather than facilitating action. Some of these real and perceived limitations of science can be overcome by exploring the knowledge held and used by different groups about the ecosystems in which they live and work.

¹ Scotland's Moorland Forum is a partnership of 28 organisations that engages with matters influencing the uplands of Scotland, and actively promotes improvements in policy, practice and management (<http://www.moorlandforum.org.uk/>).

Integrating different types of knowledge in the decision-making process can improve the quality of decisions, through the inclusion of local stakeholder values and interests. In turn, collectively agreed decisions that acknowledge local concerns and knowledge makes them more likely to be socially and politically accepted, and can contribute to resolving conflicts between different parties. There are, however, challenges in integrating different types of knowledge, including practical challenges linked to accessing local knowledge, concerns around power-sharing between state and non-state stakeholders and the perception that local knowledge may be “*insufficiently objective and insufficiently rigorous in terms of methods and documentation*”, thereby somehow lacking in scientific merit. [Read a full introduction to these knowledge types and their integration, including references cited, here.](#)

Scotland’s Moorland Forum recognised the need to overcome the above challenges and find ways of bringing together scientific and local knowledge to examine the role of predation in influencing populations of ground-nesting birds. It also recognised that a truly collaborative approach was required, to involve as broad a range of interested stakeholders as possible from project inception right through to delivery and reporting of the findings. Those stakeholders collaborated from the outset to define the scope of the project. It was agreed that an up-to-date review of the broader ecological literature (termed ‘natural science’ throughout this report) on population trends of wild birds in Scotland, the factors affecting populations, and the role of predation, was required, and that this should be carried out following formal systematic reviewing methods as far as possible, and in a strictly impartial and independent manner. It was also agreed that the review should evaluate evidence both from formal published scientific studies and local knowledge from a broad range of stakeholders.

The stakeholders agreed that the project should be founded on a shared aspiration to establish and maintain balanced, healthy populations of all wild birds in Scotland and their predators. Following further discussion, they elected to focus a large part of the project around six focal ground-nesting wild bird species (below). There were widely held concerns about recent population declines of these species and a common desire among participating stakeholders to find ways of reversing these declines. The project sought to review the recent population changes of these six species, evidence for the factors driving these changes (including predation), and evidence for the success, or otherwise, of various types of management aimed at positively influencing these populations. It was also agreed that the project should take a novel approach, by collecting evidence in a rigorous and equitable manner both from the scientific literature and from a broad range of stakeholders. This was used to establish the extent to which scientific and local knowledge agreed and disagreed. Establishing the commonalities between these two forms of knowledge should help to build consensus. Establishing differences, and exploring the reasons for these, should identify where there may still be knowledge gaps or areas of contention that may limit positive progress if they are not resolved.

Aims and objectives of the project

The over-arching aim of this review was to build a shared and accessible evidence base that collated and critically assessed the available information from science and stakeholders, highlighted where these forms of knowledge agreed or disagreed, and analysed the reasons for any differences.

There were three project objectives:

- i) Review the published scientific evidence of predator-prey interactions where relevant to the Scottish context, building on Park *et al.* (2005, 2008) and focusing on species trends, drivers of change in populations, the impact of predators on their prey and the existing evidence for the success or otherwise of alternative management options;
- ii) Establish stakeholder knowledge and management experience of predator-prey interactions, examining the arguments and evidence supporting these;
- iii) Identify and explore the reasons for uncertainties and gaps in comparisons between the science and stakeholder knowledge.

Focal species

A broad range of stakeholder members of Scotland's Moorland Forum agreed on six wild bird prey species in upland and lowland systems as particularly important foci for parts of this research:

Black Grouse Curlew Golden Plover Grey Partridge Lapwing Oystercatcher



These prey species were selected because of shared concerns for their conservation due to perceptions of recent major population declines. As agreed in the project scope, they received more prominent and detailed treatment throughout the project. A conscious decision was taken not to include Red Grouse amongst the focal species because of existing polarised views around the management of this species and predatory birds of prey.

A small number of common predators were also selected by the Research Group for use as foci in the stakeholder engagement work:

Buzzard Carrion Crow / Hooded Crow (grouped as 'crows') Raven Red Fox (often simply termed 'fox')



Two predator species, the Carrion and Hooded Crow, were grouped simply as 'crows' for the purposes of the project because they are very similar ecologically and some groups of stakeholders do not generally distinguish between them.

Whilst these wild bird prey and predator species formed the focus of the work to compare natural science and local knowledge findings, a more comprehensive range of terrestrial wild bird species, and their bird and mammal predators, were considered within the report, as agreed in the original scope.

Structure of the reporting

The Summary Report is intended to present the main findings of the project in an accessible and synthesized form. To this end, introductory and methods sections have been kept as concise as possible. References to scientific literature have been removed but full citations can be found in the Supplementary In-depth Material. Links to sections of Supplementary In-depth Material, where more detailed treatment of topics can be accessed, have been provided throughout the Summary Report.

2. REVIEWING METHODS

2.1 Social science methods

The social science element of this research was conducted in three stages: (1) 400 quantitative, web-based questionnaire were completed by representatives of organisations with an interest in the predation of wild birds in upland and lowland systems in Scotland; (2) nine workshops were held to discuss the findings of the questionnaire with stakeholders in more depth; and (3) three review seminars were held to examine findings and help interpret differences between understanding of those relying on local knowledge and the natural science findings.

Invitations to participate were initially sent to 124 relevant organisations and respondents, who then identified others who might participate in the questionnaire, workshops and seminars. Access to the online questionnaire was promoted on the blog (<http://understandingpredation.blogspot.co.uk/>) so that members of the broader community could participate in the research. Our aim here was to capture the views of the Moorland Forum and related organisations and individuals with an interest in and knowledge about predation from different perspectives. Read more on [the sampling strategy](#) and [the sample of participants](#).

Questionnaire design

Posts and comments on the blog were used to help understand the perspectives of stakeholders and these informed the development of the structured, web-based questionnaire, which was designed to link with the natural science review and was piloted prior to sending out. The questionnaire focused on the following six topics ([Read more about the design of the questionnaire](#)):

- i) Organisational affiliation and socio-demographic information;
- ii) Interest in and experience of predation of ground-nesting wild birds in the uplands and lowlands of Scotland;
- iii) Preferred forms of knowledge;
- iv) Perceptions of population abundance changes in focal predator and prey species;
- v) Drivers of change in focal prey and predators;
- vi) Conservation and management of predator-prey interactions.

Classifying stakeholder groups

An iterative approach was used to classify stakeholder groups, based on the analysis of the questionnaire results. Questionnaire respondents were classified into two groups, according to the forms of information that they identified as most important when learning about predation: the 'Local Knowledge' group (211 participants) who identified 'personal field observations or field management experience' as the most important form of knowledge and the 'Scientific Knowledge Group' (110 participants) who relied primarily on 'academic/ scientific peer-reviewed articles'. There was overlap in knowledge use between the two groups. Many who stated that local knowledge was most important also habitually used scientific knowledge, and vice versa. A variety of organisations were represented within the Local and Scientific Knowledge groups. This classification was supported by members of Project's Steering Group. [Read more about classification of stakeholders](#)

Workshop and seminar programmes

Nine workshops were conducted with 15 organisations. Workshop discussions lasted approximately two hours and explored reasons for potential divergence of views between stakeholder groups and between the stakeholders and the findings from the natural science review ([Read more about the workshop programme](#)). Workshop groups were also classified into local knowledge workshop groups (6 groups) and scientific knowledge workshop groups (3 groups). Workshop reports following the workshops were all approved by participants.

Three, one-day seminars were held to jointly discuss the preliminary findings. Discussions focused on key results, on areas of agreement and disagreement between questionnaire and natural science review findings and on developing shared ideas for future collaborative work ([Read more about the seminar programme](#)).

Comparison of knowledge

Throughout this report, we first compare the findings between the Local Knowledge and Scientific Knowledge groups. We then compare the responses of each of these groups with the information from the natural science review.

2.2 Natural science methods

Population trends of predators and wild bird prey

The review synthesized data and published science on population trends since 1960. A new Scottish and regional analysis of recent changes in wild bird populations was also undertaken based on information from the [BTO/BirdWatch Ireland/SOC Bird Atlas 2007-11 project](#). The focus of the review is Scottish trends, but these are considered in the context of UK/European/global population status and change.

The review includes all bird species on the General Licence 01-03 (see <http://www.snh.gov.uk/protecting-scotlands-nature/species-licensing/bird-licensing/general/>) and those contributing to the farmland and upland elements of the Scottish Wild Breeding Bird Indicator

(<http://www.snh.gov.uk/docs/B536405.pdf>), with the exception of fish-eating birds. For predatory mammals, the reviewing includes all those species relevant to interactions with wild birds, including feral cats. [Read more on population trends research methods, data sources and analytical approaches](#)

Review of natural science literature

The project reviewed four areas:

- drivers of change in predator and wild bird prey populations (including a full range of environmental and direct human influences e.g. afforestation, agriculture and other land-use change, climate change, legal and illegal predator control, recreational disturbance). For migratory bird species, influences outside as well as within Scotland and the rest of the UK were considered;
- relationships between predators and wild bird prey populations, drawing out both positive and negative aspects of predation;
- key interactions in relation to three focal groups: upland waders; lowland waders; and wild gamebirds and six focal prey species; and
- management experience (the evidence for the success, or otherwise, of a range of recognised conservation-management options).

The principles of a formal systematic review were adopted. The online literature database Web of Science (WoS) was searched for relevant literature using pre-defined search terms. Searches aimed at identifying literature relevant to the four areas identified above. Search terms were constructed to balance the volume of literature returned with the scope and comprehensiveness of the search. As well as this structured searching, literature recommended by stakeholders and flagged by previous reviews on related topics was also evaluated. All literature considered was subjected to formal critical evaluation criteria, which dictated what was included in the final review. [Read more on literature reviewing approaches, search terms and evaluation criteria](#)

3. HOW DO STAKEHOLDERS GAIN AND USE KNOWLEDGE?

Knowledge relates to our understanding of the world around us and how we interpret our experiences and thoughts. In this study, we acknowledge the dynamic and often biased nature of knowledge which is acquired through “*complex and ongoing processes involving selection, rejection, creation, development and transformation of information*”. Read more about knowledge and how we framed the concept of knowledge in this study [here](#).

In this study, we first explored the reasons people gave for relying on their local knowledge or on scientific assessments. Respondents claiming to rely mainly on local knowledge valued peer knowledge, and the first-hand experience of witnessing predation and the impact of changes in environmental conditions, including habitat quality. They felt that these experiences provided them with an unparalleled breadth and depth of understanding. They regarded their observations as reliable and unbiased, whereas they often mistrusted science, and in particular, how scientific evidence was

reported because of perceived biases relating to who funds, reviews, sets objectives and/or frames a study, and other problems related to spatial and temporal scale.

Those claiming to rely mainly on scientific knowledge considered that decision-making in such an emotive area as predation should be unbiased and independent, and that this would best be achieved through academically robust studies, preferably conducted by scientific organisations with significant relevant experience. They valued repeatable experiments based on facts and sound observation and the application of data analyses to reduce bias and measure the statistical significance of findings. Peer-review was also considered paramount to the success of scientific research because it allowed scrutiny by well-qualified experts before publication. They highlighted the fact that decision-makers value scientific knowledge, so science is well-placed to inform legislation and predator-prey management. Some respondents criticised what they saw as a historical reliance on circumstantial evidence which they suggested could polarise views. They mistrusted non-scientific sources, such as news media and non-peer-reviewed literature written by non-government organisations which was sometimes viewed as politically motivated or influenced by the interests of some members.

Seminar participants considered that local and scientific knowledge together could build on the strengths of the different types of knowledge and address their weaknesses. Participants noted the need to build trust, through better communication and the early involvement of local and scientific knowledge. Integration of different forms of knowledge could be achieved through increasing opportunities for networking and creating an appropriate group to co-produce knowledge on areas where there was disagreement and bring agreed findings to policy makers. [Read more on knowledge forms here.](#)

4. POPULATION TRENDS OF WILD BIRDS AND THEIR PREDATORS IN SCOTLAND

The project confirmed that all six focal wild bird prey species had shown widespread declines across Scotland since the 1960s, with strong support for this conclusion from both the natural science review of survey data and stakeholder knowledge. More information on these focal species is provided in Section 5 below and in the in-depth report.

[Read more on population changes of the six focal wild bird prey species.](#)

4.1 Natural science review of population change for terrestrial wild birds and their predators in Scotland

The current review provides a concise summary of population changes since 1960 for most terrestrial breeding wild birds in Scotland and their main avian and mammalian predators, placing these in the context of changes at broader geographical scales.

Population trends of predatory mammals

Whilst information about the distribution, and in some cases abundance, exists for some UK mammals, this is very sparse for other species, and robust information on population trends is often lacking, in part due to difficulties of observing mammals (which can occur at low densities; are often nocturnal and elusive; and may also require species-specific survey designs; [Read more about mammal population data sources](#)).

There is evidence that populations of several predatory mammal species have increased in Scotland since the 1960s, including Grey Squirrel, Red Fox (until quite recently), Pine Marten, Polecat, Otter and probably Badger (populations of which have increased at UK level and, although Scotland-specific trends are not available, it is likely that they have also increased here, too) and Brown Rat (although the increase is not quite significant for Scotland). Reduced human control has played an important role in the increases for some of the species, plus expansion of non-native population (Grey Squirrel) and probably urban expansion for Brown Rat. Weasel and Stoat, and probably Feral Ferret, populations are thought to have remained relatively stable overall. Populations of European Hedgehog (due to agricultural intensification, increased road traffic, urbanisation and predation by other mammals, such as Badger), American Mink (due to culling and increase in Otter populations) and Ship Rat (due to improved human hygiene and growth of Brown Rat populations) are considered to have declined. Red Squirrels have shown mixed fortunes in Scotland, and detailed information on Wildcats is lacking.

Predatory mammal species accounts for more information

[European Hedgehog](#)

[Red Squirrel](#)

[Grey Squirrel](#)

[Common \(Brown or Norway\) Rat](#)

[Ship \(Black\) Rat](#)

[Red Fox](#)

[Pine Marten](#)

[Stoat](#)

[Weasel](#)

[Polecat](#)

[Feral Ferret](#)

[American Mink](#)

[Badger](#)

[Otter](#)

[Wildcat](#)

[Feral/Domestic Cat](#)

Population trends of predatory birds

For birds, the review contains a new synthesis of information from the Bird Atlas 2007-11 project ([Read more about Bird Atlas 2007-11 and analytical methods](#)) at the scale of Scotland and its constituent regions but also draws on the results of other long-term monitoring schemes and periodic surveys ([Read more about data sources for population trends](#)).

Since the 1960s, many species of birds of prey and Raven have shown increases in abundance and recovery of breeding range following some deliberate reintroductions, and relaxation (though not elimination) of human pressures on their populations, including secondary poisoning by organochlorine pesticides and targeted control by humans. These changes have been regionally variable however, with a more recent tendency for continued increases in the lowlands but less positive population trends in upland areas. Some of the other corvid populations have also shown range expansion and increases in

abundance, particularly in the lowlands, presumably at least partly as a result of relaxation of control by humans, although the patterns are less pronounced than for the birds of prey afforded greater protection. Predatory gulls and skuas reached high populations soon after the 1960s following long periods of population growth driven by increased food availability, such as from fisheries discards and human refuse. They have since declined, however, partly due to deliberate control in some areas but more extensively through restrictions on discarding by fisheries and changes in refuse management.

Predatory bird species accounts for more information

Birds of prey

[Common Buzzard](#)
[Red Kite](#)
[White-tailed Eagle](#)
[Hen Harrier](#)
[Golden Eagle](#)
[Goshawk](#)
[Sparrowhawk](#)
[Kestrel](#)
[Merlin](#)
[Peregrine](#)
[Tawny Owl](#)
[Short-eared Owl](#)

Skuas and gulls

[Arctic Skua](#)
[Great Skua](#)
[Black-headed Gull](#)
[Common Gull](#)
[Lesser Black-backed Gull](#)
[Herring Gull](#)
[Great Black-backed Gull](#)

Corvids

[Carrion and Hooded Crows](#)
[Magpie](#)
[Jay](#)
[Jackdaw](#)
[Raven](#)

The latest comprehensive information on changes in distribution and relative abundance of Scottish terrestrial breeding birds is summarised in the main report and a series of appendices. [Read more on population changes of other Scottish terrestrial wild bird species.](#)

4.2 Stakeholder perceptions of population trends for wild birds and their predators

Both stakeholder knowledge groups perceived that populations of Buzzard, Carrion/Hooded Crow, Raven and Red Fox have increased, whilst the six focal prey species populations have declined (Figure 1a). Nevertheless, there were differences between the groups. The Local Knowledge group considered that the predator populations have increased significantly more than did the Scientific Knowledge group. They also disagreed over change estimates for Golden Plover, Grey Partridge and Oystercatcher. One reason that could explain these differences is that stakeholder groups had varying experiences with these species at different geographic scales and locations. [For more information, read here](#)

4.3 Population trends of wild birds and their predators in Scotland – comparison of stakeholder knowledge and natural science findings

Overall, there was broad consensus between stakeholder knowledge and the Atlas data about how the abundances of different species have changed (Figure 1). However there were differences for some species. The largest differences were in relation to Carrion/Hooded Crow, with both knowledge groups overestimating their population change relative to the Atlas. There were also some differences in

relation to Raven and Golden Plover (Local Knowledge *versus* Atlas), and for Buzzard, Raven, Grey Partridge and Oystercatcher (Scientific Knowledge *versus* Atlas).

The Scientific Knowledge group significantly underestimated the increase in Buzzards and Ravens compared with the Atlas data (Figure 1c). The Atlas data for Grey Partridge and Oystercatcher suggested a significantly greater decline in these species than estimated by the Scientific Knowledge group. Despite these significant differences between Local and Scientific Knowledge groups, and between the assessments from these groups and the Atlas estimates, these knowledge groups, sources of information (Atlas or stakeholder) and any interactions between them explained less than 9% of the variation between abundance estimates. This reinforced the conclusion of a generally high degree of consensus between the two knowledge groups and the Atlas about how the abundances of different species have changed.

Workshop participants suggested several reasons why their assessments differed from those of the Atlas, many of which related to: how bird counts are conducted; difficulty of assessing some species accurately due to highly mobile (e.g. corvids), non-breeding, and therefore un-surveyed, components of some populations (e.g. Buzzard), fluctuating populations (e.g. Black Grouse, Oystercatcher); and stakeholder perceptions and ecological knowledge about particular species (e.g. species that are more important to stakeholders may register more than those that are less important/well known).

Seminar participants suggested a variety of reasons to explain differences in Carrion/Hooded Crow population trend assessments. These included ideas relating to stakeholders' values, problems with species identification, effects of corvids being attracted to areas with more prey availability, lifecycle factors (e.g. territorial and non-territorial/wandering populations, interbreeding), Atlas monitoring methods, socio-ecological changes affecting populations in some areas (e.g. intensified farming practices, changes to legislation and culling techniques) and varying levels of stakeholder contribution in terms of managing crow populations (e.g. varying levels of management effort among different sectors and reporting local observations to BTO). [Read more here](#)

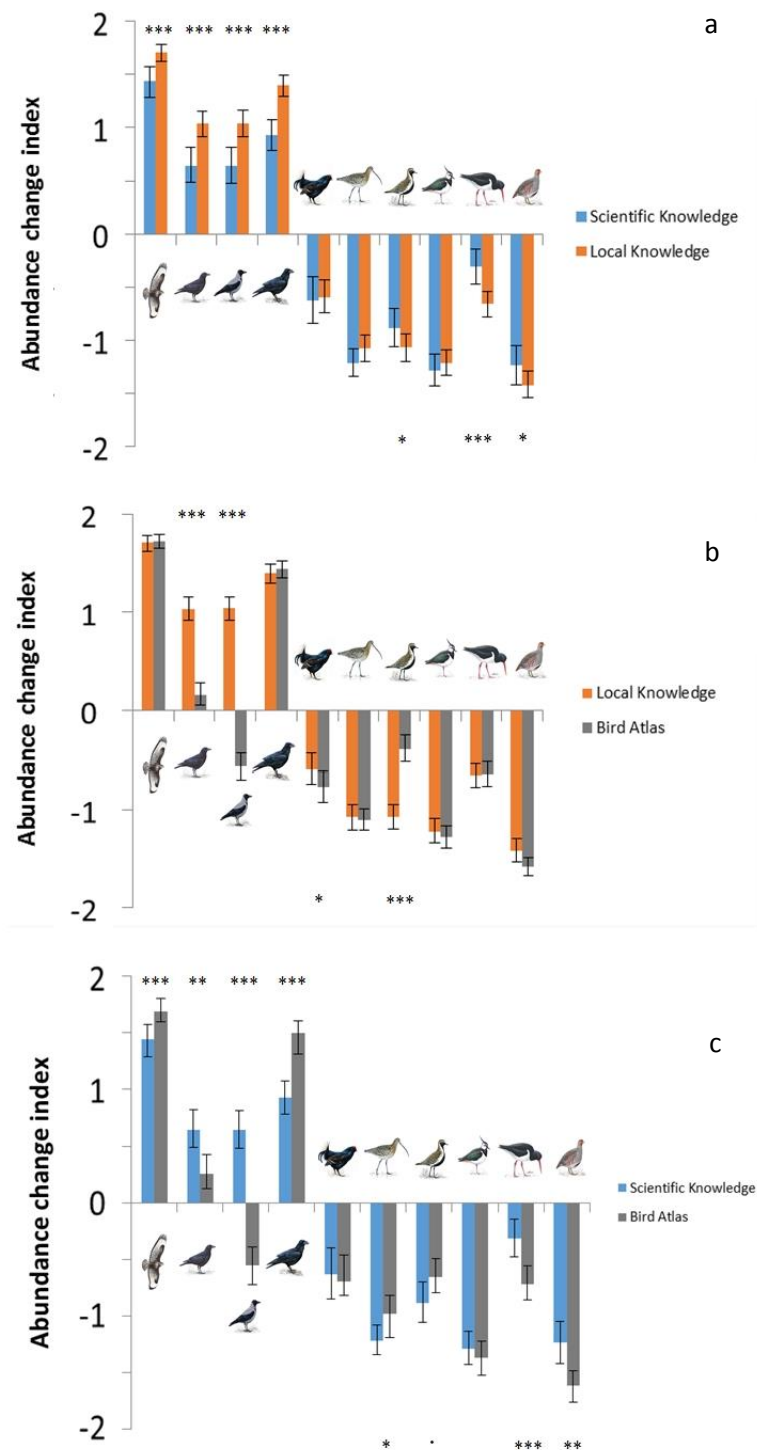


Figure 1. Average abundance change indices (with bars indicating 95% confidence intervals) for 6 prey and 4 predator species over the last 25 years as estimated by a) Local Knowledge and Scientific Knowledge groups, b) Local Knowledge groups and equivalent data from the Atlas data, and c) Scientific Knowledge group and Atlas data. No Atlas data were available for Red Fox. * = P<0.05, ** P<0.01, *P<0.001**

5. DRIVERS OF POPULATION CHANGE OF WILD BIRDS, INCLUDING THE ROLE OF PREDATION

5.1 Natural science review of drivers of population change for wild birds and their predators

Difficulties of assessing the relative importance of population drivers

The impact of predation on wild bird populations can be difficult to determine as evidence of mortality does not necessarily mean that predation is driving population declines. The strongest way in which population-level effects can be attributed to predation relies on experimental evidence, which is often not available. Many studies are correlational, and while efforts are often made to account for potentially confounding variables, strong relationships (or the apparent absence of relationships) can render such studies inconclusive. Even when studies are experimental, relationships can be confounded by increases in predation by other species; few published studies clearly distinguish between the effects of different predator species. Often there is a lack of rigorous data on predator populations, resulting from a tendency of studies to focus on prey populations, and studies may use indirect measures of abundance, some of which are difficult to interpret. This particularly applies to assessments based on numbers killed as these are affected by several factors other than population size. Read here for more detailed background on: [difficulties of assessing the impacts of predation](#); [relationships between predator species](#); and [responses of predators to variation in prey numbers](#).

In addition, the interactions between predation influences and those of other factors are often important, and there is strong evidence for such interactions in the scientific literature. The project considered a broad range of other putative drivers of wild bird population change (read here for more general consideration of: [climate and weather](#); [habitat and land-use impacts](#); [disease and parasites](#); [other human impacts](#)).

During the project, when comparing the importance of different factors driving change in populations of the six focal prey species as recognised through stakeholder responses and the scientific literature, we gave each factor a rank score. For the scientific reviewing, the scores were derived according to the evidence base that supported them, taking into account the number of relevant studies and consistency of their findings, the design and scale of the available studies, where studies were carried out (i.e. relevance to the Scottish context) and the strength of any driver effect found. Interactions between different drivers were not included in the scoring because there was no need to compare them with the stakeholder findings. The scoring provided some assessment of the relative influences of the different drivers as evidenced in the scientific literature but cannot control for biases in the scope of original research.

FOCAL SPECIES – BLACK GROUSE

Black Grouse experienced a long-term contraction of range and decrease in abundance from the late 1800s onwards. Some temporary increases or range expansions have been associated with afforestation in Scotland and, in recent decades, with targeted conservation and moorland management initiatives.

More recent declines have been linked to forest maturation. [Read more about Black Grouse population changes](#)

Studies vary according to the importance they ascribe to adult survival and productivity for driving population changes of this species. A large number of studies have considered the influence of predation on Black Grouse. Predation is widely recognised as a proximate cause of breeding failure, with some studies suggesting strong effects on adult survival. It seems likely that the combined effects of predation on productivity and survival will be sufficient, at least in some situations, to strongly affect rates of population change, though few studies clearly demonstrate such an influence.

Although it is difficult to disentangle the separate effects of different predator species on Black Grouse one or more studies have clearly demonstrated the potential importance of foxes, mustelids and corvids as nest predators, and have shown that foxes, mustelids and raptors (including Peregrine, Goshawk and Golden Eagle) can be important predators of adults. Several studies in Scandinavia have shown that predation rates of Black Grouse can be affected by availability of other prey species, suggesting that functional (and possibly numerical) responses of predators to changes in prey species composition can be important for Black Grouse populations.

Habitat and land-use changes are important drivers of Black Grouse populations. Moderate levels of grazing have been shown, by several studies, to benefit Black Grouse. Increased stocking densities on moorland can impact negatively on Black Grouse populations by reducing sward height and diversity of plants and, consequently, the availability of invertebrate food for chicks. Habitats in Britain recently associated with high Black Grouse productivity include heather moorland and young native pinewoods. However, forestry is also associated with ongoing negative impacts through its influence on populations of predators, and the impacts of drainage and forest maturation on habitat suitability. Recreational disturbance and collisions with power lines and fences were found to have little impact on Black Grouse. There is also little evidence that diseases and parasites drive population changes in Black Grouse. It is unclear what impacts climate change will have on Black Grouse populations. [Read more about drivers of change of Black Grouse populations](#)

FOCAL SPECIES - CURLEW

Curlew were widespread following periods of range expansion up to at least the 1960s but subsequently experienced major declines in both breeding range and abundance, most markedly in the west of Scotland (with the exception of the Western Isles). [Read more about Curlew population changes](#)

In common with other waders, recent declines of Curlew populations are largely due to impacts on productivity. Experimental control of generalist predators, and relationships between breeding density and nest success with gamekeeper activity at a landscape level, strongly suggest that predation by generalist predators such as foxes and crows can limit breeding densities of Curlew. However, the main reasons for Curlew decline are thought to be various aspects of (primarily lowland) agricultural intensification and, particularly in the south-west of Scotland, loss of suitable habitat to afforestation.

Drainage and fertilisation affect the availability of suitable nesting habitat and susceptibility of available nest sites to predation. Earlier spring grass growth, earlier cutting dates and higher stocking levels have reduced food availability and increased mortality due to predation and farming operations. Some of the relationships between Curlew populations and habitat may have been caused by the predation risk varying with habitat. Curlews are susceptible to tick infestations but this is unlikely to have population-level impacts. Recreational disturbance may reduce Curlew populations. Curlews are predicted to decline in Britain in response to climate change due to the way in which their current distribution in Scotland is related to variation in climate. [Read more about drivers of change of Curlew populations](#)

FOCAL SPECIES – GOLDEN PLOVER

Since the late 1960s, this species has experienced range contractions, most markedly in the Southern Uplands and southern and eastern Highlands. Declines in abundance have not been uniform across Scotland, however, with some areas (e.g. the central Highlands) showing increases. [Read more about Golden Plover population changes](#)

Golden Plover populations appear to be influenced by factors affecting both survival and breeding success and there are examples of population abundance having been affected by weather, habitat and predation. In Britain, experimental reductions of corvids and foxes have successfully increased breeding success and numbers of Golden Plover at a local scale, but have largely not resolved the relative importance of different predator species, or the extent to which control of one species might result in compensatory increases in predation by others. In European populations where declines appear to be related to effects of predation on productivity, the majority of predation has been attributed to Red Fox. However, even where losses of eggs or chicks to predators are relatively high, the potential for predator control to increase the productivity of Golden Plover populations may be constrained by other factors, such as food availability.

The regional extinction of a breeding Golden Plover population in the north east of Scotland is likely to have been caused, at least in part, by survival during very cold winters on their Scottish wintering grounds in the 1970s and 1980s. Climate-driven phenological mismatch and prey declines are also detrimental to Golden Plovers, and predicted to be of major importance in the future. Golden Plover breeding density correlates negatively with vegetation height, probably reflecting invertebrate prey availability. Population declines have also been associated with displacement due to afforestation and proximity to forest edges, probably due to increased predation. There is some evidence for impacts arising from recreational disturbance on Golden Plover populations. [Read more about drivers of change of Golden Plover populations](#)

FOCAL SPECIES – GREY PARTRIDGE

This species has shown marked declines in both range and abundance in Scotland since the 1960s, with extensive losses in the south and west of Scotland in particular. [Read more about Grey Partridge population changes](#)

Grey Partridge populations are driven principally by factors affecting productivity. Foxes and corvids have been identified as important predators of Grey Partridge, with Sparrowhawks, mustelids, rats and feral cats also contributing to predation impacts. Strong effects of predator control on productivity and population levels have been demonstrated experimentally, in studies involving control of foxes and corvids. Observational studies suggest that Sparrowhawk predation of adults in late winter and early spring could cause population declines, particularly at low densities of Grey Partridge. Interpretation of correlative associations between raptor densities and Grey Partridge density is complicated by relationships between raptor densities and shooting intensities. Grey Partridges in large coveys may experience a lowered risk of predation.

There is a close link between Grey Partridge population change and chick survival rate, which is largely driven by invertebrate availability. The main proximal cause of the ongoing decline of Grey Partridge in the UK is reduced productivity due to lack of insect food for chicks, which in turn is considered a result of the introduction and intensification of agrochemical applications in the 1950s. The effect of vegetation structure on concealment from and detection of predators has also impacted negatively on this species. Other factors that may have contributed to wild population declines include the spread of the parasite *Heterakis gallinarum* by pheasants and hunting in areas where captive-reared gamebirds are released. There is a lack of information about the likely impacts of climate change on Grey Partridge. [Read more about drivers of change of Grey Partridge populations](#)

FOCAL SPECIES - LAPWING

Having increased in the 1800s, with apparent population stability until the mid 1960s, this species has subsequently undergone extensive declines in abundance and loss of breeding habitat, particularly in the west of Scotland. [Read more about Lapwing population changes](#)

In common with several other European wader species, recent population declines are linked to declines in productivity rather than adult survival. Unsustainable rates of Lapwing nest depredation have been found by many studies, despite the ability of Lapwings to replace lost clutches of eggs. Typically, loss of eggs is (in some areas) is considered to be due to mammal predation, whereas chicks are commonly taken by both mammals and birds. Evidence from many studies does not allow the effects of different predator species to be reliably distinguished from one another. This is, at least in part, due to the tendency of other predator species to compensate (numerically and/or functionally) when a particular predator is experimentally controlled. However, there is good evidence that excluding mammalian predators such as foxes and badgers from nests can greatly increase Lapwing productivity. In the Western Isles, predation by non-native hedgehogs has a severe impact on Lapwing breeding success and population growth. Other studies strongly suggest that corvids can reduce Lapwing productivity and

population size. The role of raptors in regulating Lapwing populations is less clear, but effects of Sparrowhawk and Buzzard have both been suggested by correlative studies. The effect of predation is commonly mediated by habitat due, in large part, to the effect of vegetation height on parental vigilance, which plays a crucial role in Lapwing anti-predation behaviour.

Several studies indicate that the low breeding success underlying Lapwing population declines is due in large part to habitat loss (largely due to conversion of arable farmland to grassland, but with losses to afforestation in the mid-20th Century contributing in upland areas) and agricultural intensification. This led to lack of suitable breeding habitat, increased risk from livestock trampling and farming operations, and lower abundance of invertebrate food sources for chicks. Lapwing populations have been found to respond to weather variables but the influence of climate change is not clear. [Read more about drivers of change of Lapwing populations](#)

FOCAL SPECIES - OYSTERCATCHER

Having experienced a marked range expansion in Scotland until the late 1960s, this species has shown some declines in abundance in mainland Scotland subsequently. [Read more about Oystercatcher population changes](#)

Although Eurasian Oystercatcher populations are stable or increasing over much of their global range, this species is undergoing rapid declines over much of Europe. There is little research into whether populations are driven by factors associated with survival or breeding success. There is some evidence that, in common with other breeding wader species in the Western Isles, Oystercatcher population growth rates were reduced by hedgehog predation. However, the large size and aggression of Oystercatchers may make them less vulnerable to predation by small predators such as hedgehogs. Proximity to nests of avian predators, which include corvids and large gulls, can negatively influence Oystercatcher nesting density and success.

Agricultural intensification, reduced eutrophication of inter-tidal feeding areas and over-exploitation by mechanical shell-fisheries have all been put forward as possible contributors to European declines. Relatively short periods of severe winter weather can greatly reduce survival by limiting food availability. Although climate change will increase average winter temperatures, the influence on extreme weather events (including cold snaps) is less certain, so the overall effect of future climate change on Oystercatchers remains unclear. Habitat can exert an influence on Oystercatchers by affecting food availability. Grazers can contribute to habitat impacts but can also directly affect Oystercatcher productivity by causing egg loss, although the population impacts of this are not known. Oystercatcher densities can also be negatively impacted by recreational disturbance and proximity to roads, but the fact that this species now breeds on flat rooftops in many parts of Britain suggests that this species can, in some situations, be tolerant of human presence and activities. [Read more about drivers of change of Oystercatcher populations](#)

UPLAND GAMEBIRDS

There is better evidence of population level effects of raptor predation on Red Grouse in Scotland than there is for any other avian prey species. There is also good evidence that other generalist predators, particularly corvids and foxes, but also mustelids, can limit numbers of Red Grouse and Capercaillie. Evidence for effects of Pine Marten predation on Capercaillie is mixed and difficult to interpret with certainty. Red Grouse is one of the few species for which disease can have a population-level impact. Population cycles caused by the nematode *Trichostrongylus tenuis* are known to be a natural phenomenon. However, population impacts of diseases tend to be higher in areas where it is the focus of land management, due to the exceptionally high grouse densities, unless disease risk is managed (prevalence of strongyle worm is now greatly decreased by medicated grit). Increasing temperatures and rainfall could increase the frequency and intensity of disease outbreaks in Red Grouse. Climate change could pose a particular problem for high altitude birds such as Ptarmigan, and there is evidence that phenological mismatch between moult and snow arrival could increase predation risk in this species. Habitat availability is an important factor for both Red Grouse and Capercaillie, due to its effects on both food availability and predation risk. In Scotland, mortality due to fence collisions has frequently been recorded in upland game species. Fence removal and marking is likely to have ameliorated population impacts of fence collision. Mortality due to collisions with ski infrastructure and power lines has been observed across Europe in upland gamebirds. However, effects on populations are unclear and no relevant research has been conducted in Scotland since 1979. [Read more about drivers of change of other upland gamebird populations](#)

UPLAND WADERS

Other upland wader populations are likely to be subject to similar predation pressures as described for Golden Plover and Curlew. Other relevant factors for this group include drainage, grazing intensity and other aspects of agricultural intensification, as well as establishment of forest plantations in open, upland habitats. [Read more about drivers of change of other upland waders](#)

OTHER UPLAND BIRDS

Predation, climate change and agricultural intensification are likely to be among the most important population drivers of passerines and other upland species, with different combinations of these variables being important for different species. [Read more about drivers of change of other upland birds](#)

LOWLAND GAMEBIRDS AND WILDFOWL

Predation, hunting pressures (particularly where unregulated) and, increasingly, disease, all affect populations of species in this group, with different combinations of these variables being important for different species. [Read more](#) about drivers of change of lowland gamebirds and wildfowl.

LOWLAND WADERS

Predation is important for this group, both in its direct effect on breeding productivity and also on mortality (both direct and indirect) over winter. Various aspects of agricultural intensification are also important, including grazing intensity, cropping regimes and drainage. [Read more about drivers of change of other lowland waders](#)

OTHER LOWLAND BIRDS

Clear evidence of predation effects is scarce or absent for most (though not all) lowland songbird populations, though several studies suggest that interactions between predation risk and other factors such as habitat use and starvation risk may have population-level impacts. Among other drivers, agricultural intensification and its consequences, particularly for seed sources in winter and invertebrates in summer, grazing-mediated changes to woodland vegetation and for, a few species, disease, seem to be particularly important. [Read more about changes of other lowland birds](#)

RAPTORS AND CORVIDS

Predation can be an important population driver of ground-nesting birds of prey. Other influences (positive and negative) on populations of predatory and scavenging birds include land-use change (particularly intensification of farmland and conversion of open habitats to forest), secondary poisoning with widely used rodenticides, and killing by humans, often in relation to management for gamebirds. Read more about the drivers of change of raptor and corvid populations [here](#) and in the individual species accounts for [raptors](#) and [corvids](#).

5.2 Stakeholder understanding of drivers of population change for wild birds

Environmental and human drivers of population change

Most respondents (73%) in the Local Knowledge group thought that predators have had a medium to high negative impact on the six prey species over the last 25 years, compared to 41% of the Scientific Knowledge group (Figure 2). In contrast, the proportion of respondents who thought habitat has had a medium to high negative impact was smaller for the Local Knowledge group (36%) than for the Scientific Knowledge group (53%). Local Knowledge respondents consistently thought that recreational disturbance was more important than those in the Scientific Knowledge group.

Most workshop participants prioritised predators over the other drivers but also strongly associated land-use change with focal species population decline. Participants from two scientific knowledge groups prioritised habitat quality and land-use change over predators as the most important drivers. There was general agreement about the relative importance of food availability, climate/weather and livestock numbers regarding focal species population decline. All workshop groups identified

herbicides/pesticides as an important driver of population change for Grey Partridge. Workshop participants agreed that drivers can interact to stimulate predator and prey population changes and that measuring the impacts of any single driver in isolation can be problematic.

In the Review Seminars, participants suggested that differences between stakeholders could be explained by the fact that a) predators in general were more visible than other potential factors, b) many predators were perceived to have increased in abundance, and c) predator control was observed to have an immediate effect, whereas other drivers such as habitat were considered to be more subtle or long-term.

Participants who have witnessed regular disturbance events expressed concern about the cumulative impact of increasing numbers of people, including walkers (often with dogs), birdwatchers, scientists and others, roaming in areas where ground-nesting birds are breeding. However, a lack of scientific studies of disturbance meant that this factor was a lower priority for most scientific knowledge participants.

Predator species perceived to drive population change

Local Knowledge group respondents were consistently more likely to consider that Buzzard, Carrion/Hooded Crow, Raven and Red Fox have had a medium to high negative impact on each of the six prey species over last 25 years than those in the Scientific Knowledge group (Figure 3). Of these predatory species, Carrion/Hooded Crow and Red Fox were considered the most important, but in total 27 species were thought to have a significant impact on the six prey species. In the Scientific Knowledge group, respondents were more likely to consider that predators have had no impact or that they were uncertain about the impact of predators.

Workshop participants broadly agreed that Carrion/Hooded Crow and Red Fox are significant predators of the six focal prey species. Raven and Buzzard were more controversial, partly due to a lack of scientific evidence to measure the extent of their impact on ground-nesting birds and partly because of their protected status. Ravens were considered to be a significant predator of ground-nesting birds but their nomadic behaviour and variations in population size across Scotland made it challenging to accurately assess their impact. Differences in opinion between local and scientific knowledge participants about Buzzards focused on their diet and the extent to which they could have an impact on both ground-nesting bird species. The protected Badger and Pine Marten, also controversial due to their protected status, were also frequently named by local knowledge participants as having a significant impact in this context.

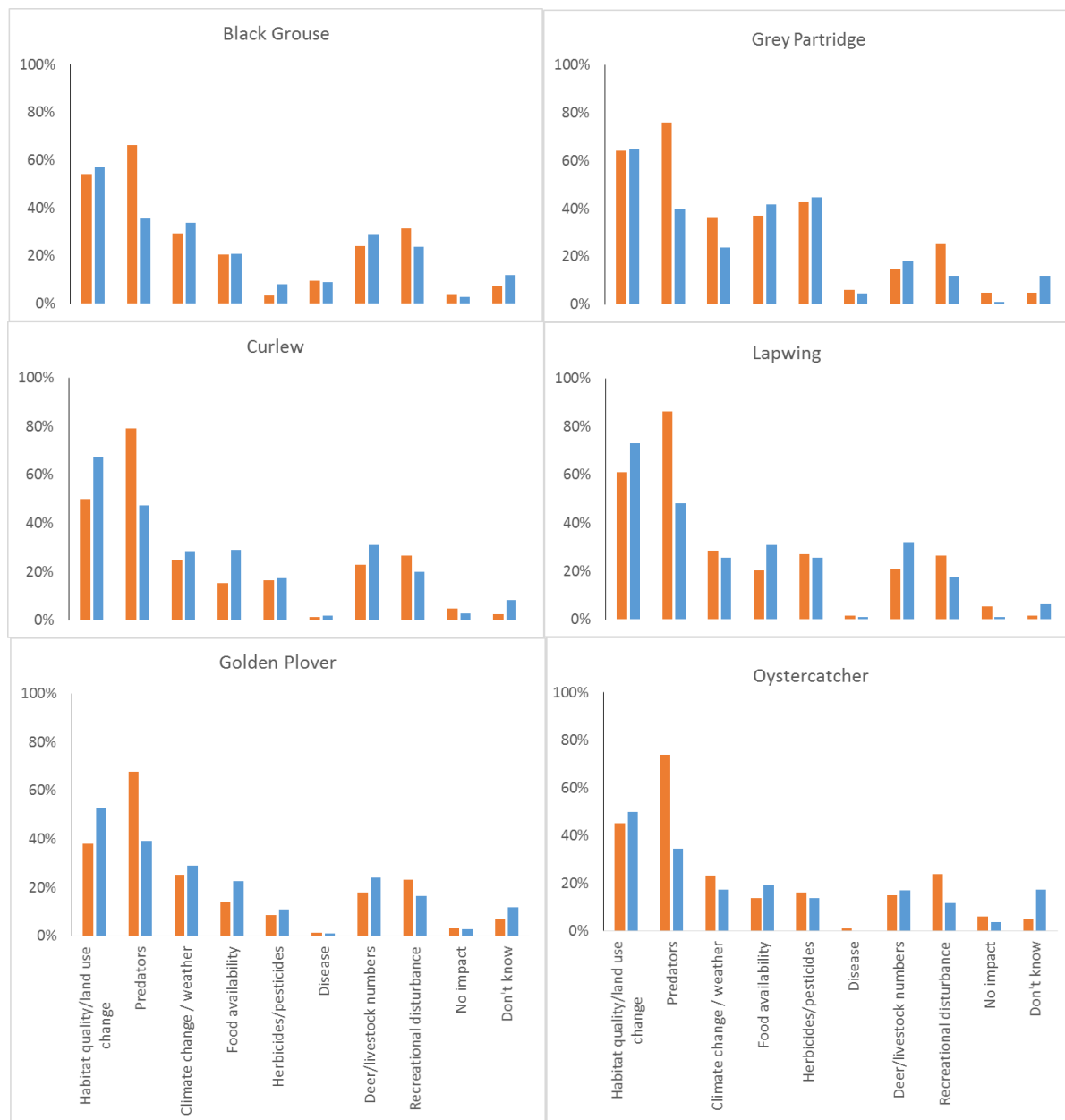


Figure 2. Percentage of respondents from the Local Knowledge (orange bars) and Scientific Knowledge (blue bars) groups who identified different environmental and human factors as having had a medium to high negative impact on the six prey species over the last 25 years. Respondents could identify more than one factor (n=321).

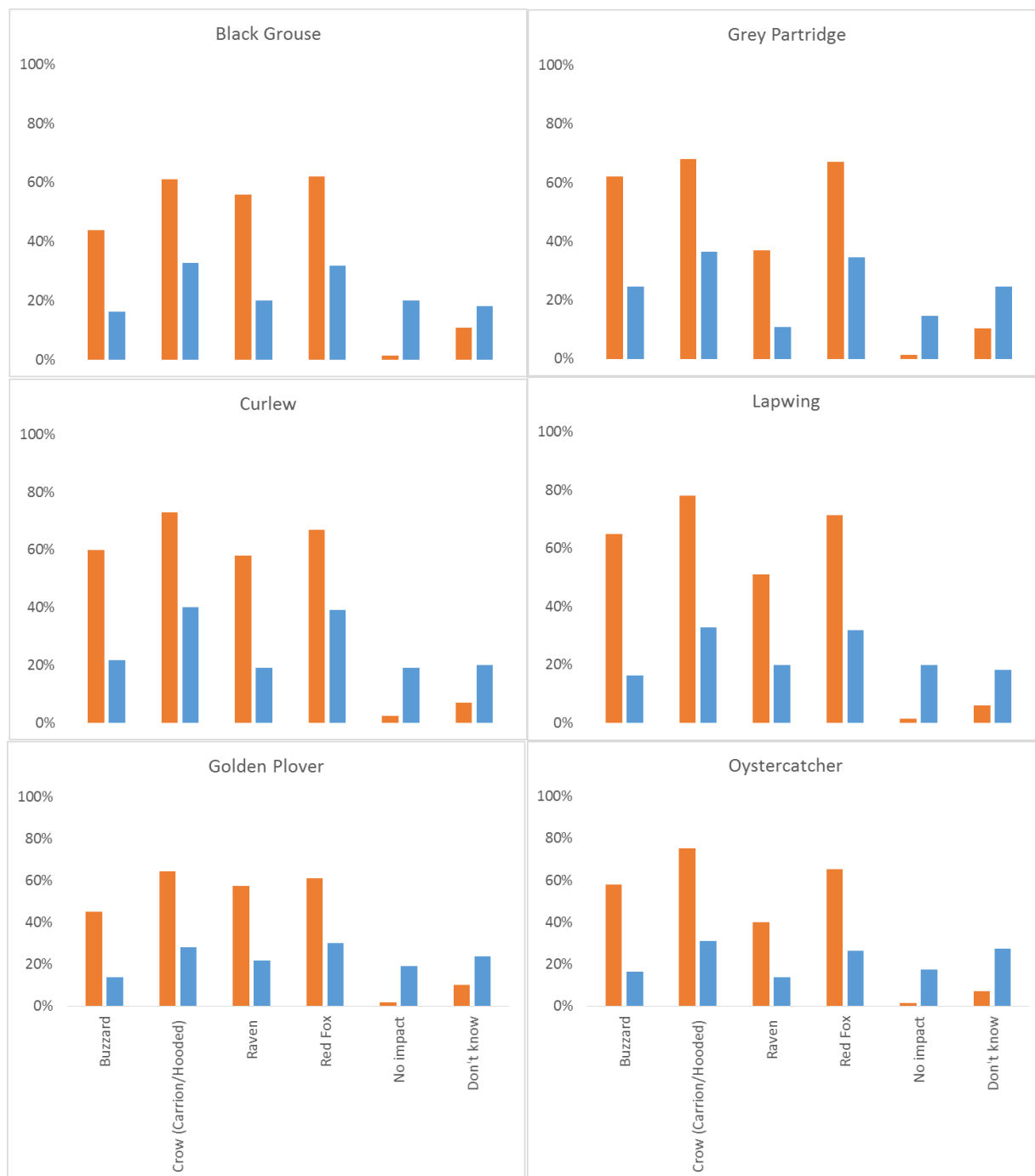


Figure 3. Percentage of Local Knowledge (orange bars) and Scientific Knowledge (blue bars) respondents who identified focal predator species as having had a medium to high negative impact on the different prey species over the last 25 years (n=321).

5.3 Drivers of population change for wild birds in Scotland and the role of predation – comparison of stakeholder knowledge and natural science findings

The environmental and human factors ranked from the scientific literature review were positively correlated with similar factors ranked by the Local Knowledge group for three of the prey species and for five of the species in the case of the Scientific Knowledge group. This suggested a general agreement in the relative importance of the impact different environmental and human factors have had on these species over the last 25 years, especially for Black Grouse, Golden Plover and Lapwing. The patterns also suggested good agreement between the Scientific Knowledge group and the scientific literature (Figure 4). There were also broad similarities between the stakeholder knowledge groups and the scientific literature in the ranking of predator species for each of the prey species (Figure 5). Estimates from all three forms of knowledge suggested that Carrion/Hooded Crow and Red Fox were more important predators than Buzzard and Raven. Seminar participants suggested a number of possible reasons why local knowledge holders may have ranked predation as the most important driver of population change in the six prey species. Predators were more visible than other potential factors and there were considered to be increasing numbers of protected predator species. Predator control was observed to have an immediate effect and may often be the only factor that can be changed, if all possible habitat management is already in place. Predator impacts were considered especially deleterious during the breeding season and in areas where prey species were depleted or more vulnerable due to other drivers (e.g. agricultural, forestry or recreational disturbance). Other drivers, such as climate change, were considered to be more subtle or long-term.

Issues of geographic and temporal scale were often mentioned, with local knowledge holders potentially reacting to more local events than scientific knowledge holders. Differences in ways of learning were highlighted by some; one participant described learning about predators by local knowledge holders as “*an unblinkered stare*”, as opposed to scientists who were perceived as relying on methods that can tend to underestimate predators, spending less time on the ground, and operating over long research time periods. A number of participants highlighted the paucity of robust scientific studies on predation, and the ambiguous results of existing studies.

Seminar participants stressed the need for more education of the public and liaison with local communities in terms of the effects of disturbance and promotion of responsible and respectful behaviours. A number of reasons could explain why local knowledge holders may have ranked disturbance higher than scientific knowledge holders. Local knowledge holders may observe disturbance and its effects on a regular basis, over a longer time frame and at a more localised level. Other potential reasons could be a perception about the effects of disturbance based on sensitive species such as Capercaillie, or skewed results based on regional differences in disturbance.

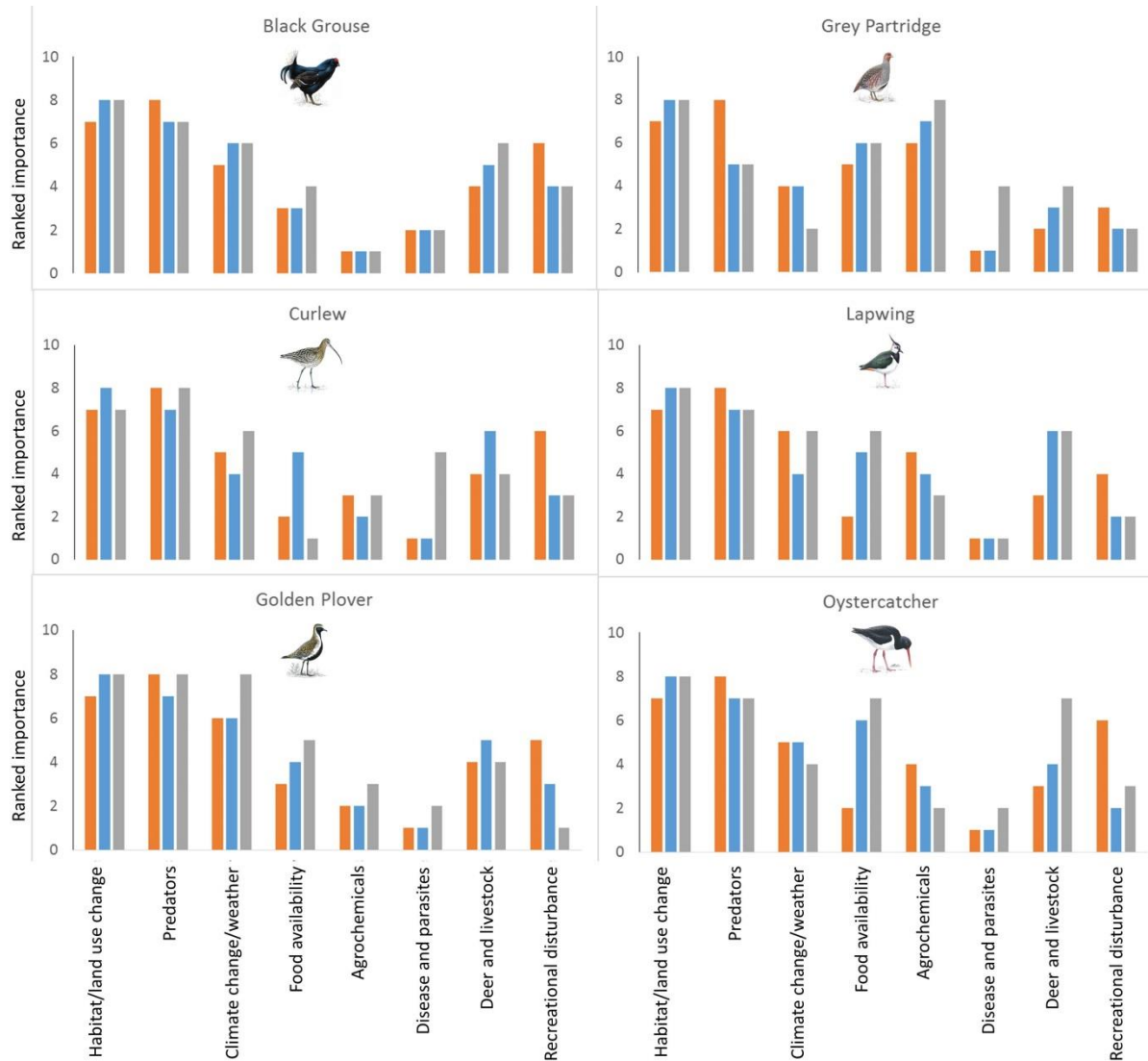


Figure 4. Comparison of the Local Knowledge (orange bars) and Scientific Knowledge (blue bars) respondents (n=321) and scientific literature (grey bars) on the ranked importance (where the rank of 8 is given to the most important driver and 1 to the least important) of human and environmental drivers of population change for the six focal prey species.

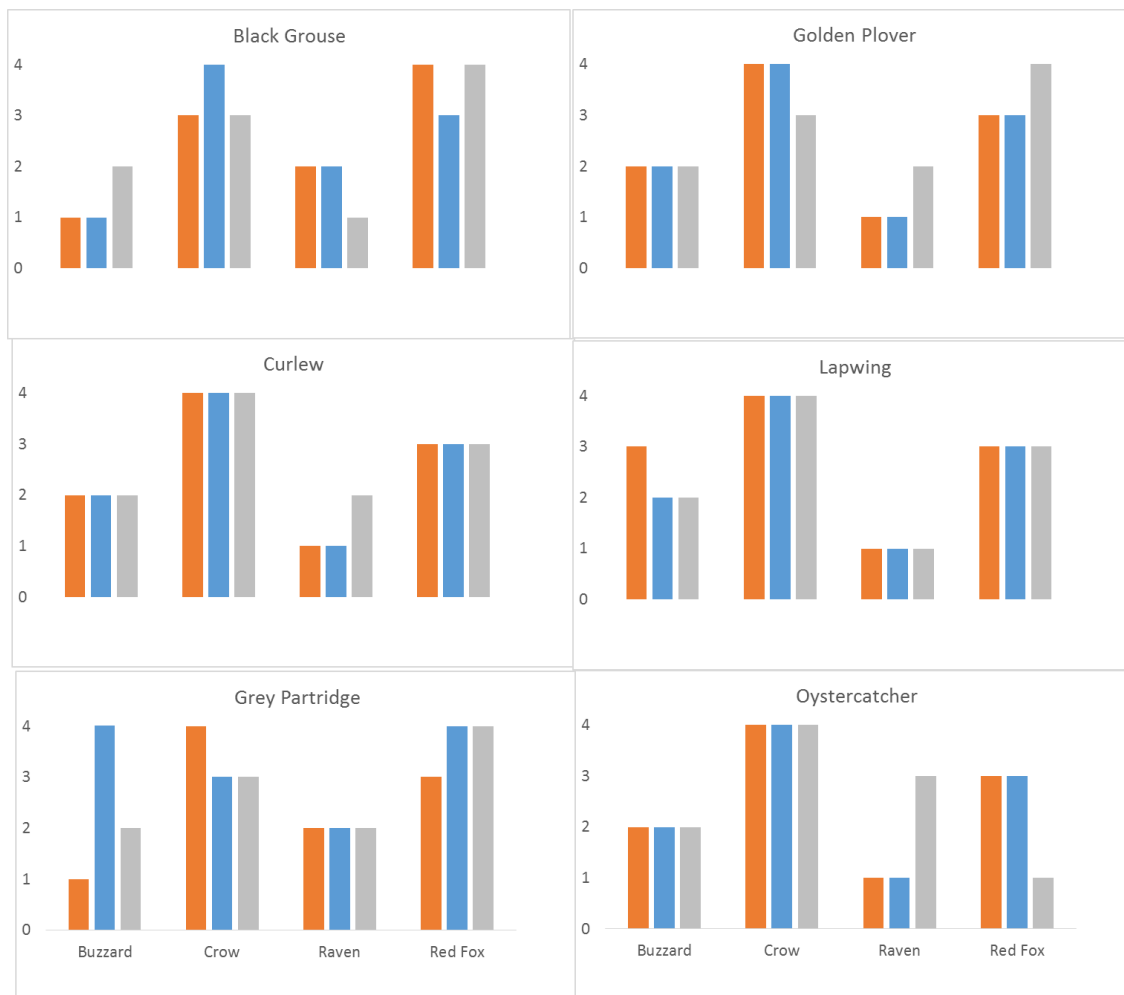


Figure 5. Comparison of the Local Knowledge (orange bars) and Scientific Knowledge (blue bars) respondents (n=321) and scientific literature (grey bars) on the relative importance of the four focal predator species on the six focal prey species. Ranks were based on the % of respondents that perceived predators as having had a medium to high negative impact on the prey population over the last 25 years (n=321).

6. CONSERVATION-MANAGEMENT OPTIONS

6.1 Natural science review of the evidence for the success, or otherwise, of conservation-management options

The natural science reviewing of this topic concentrated on conservation-management techniques that have the potential to provide positive benefits for populations of ground-nesting birds (breeding waders and gamebirds) in Scotland. Broader management that could directly benefit wild bird prey populations was included in the agreed scope of the project, alongside management that could influence predator populations and reduce predation influence.

PREDATION MANAGEMENT

Predator removal

Unless explicitly stated, consideration of predator removal in this report focuses exclusively on (lethal) predator control. This involves removing predators by killing them, and is one of the commonest forms of predator management practiced and studied. While the implications for prey are usually similar to those of non-lethal removal, predator control typically requires much less time, money and effort, and is therefore much more efficient.

The findings of several recent systematic reviews suggest that predator removal can benefit ground-nesting birds in Scotland, particularly by reducing the impacts of predation on breeding productivity. Interpretation of studies that have investigated the efficacy of predator control is often complicated by the fact that, where a suite of predator species is removed, it is difficult or impossible to know what benefits accrue from the removal of each species. When only a subset of the relevant predator species is removed, however, compensatory changes in the behaviour or number of other predators can also make it difficult to interpret the findings of a study. [Read more on predator removal](#)

Factors determining success

The effect of geographical scale in determining the effectiveness of predator removal programmes depends on a number of factors, including the mix of predator species present, their abundance on the site being managed as well as in the surrounding landscape, and the objectives of the removal programme. The response of prey populations to a given intensity of predator removal can be positively related to starting predator densities. Correspondingly, increasing effort is typically needed to realise a benefit of predator removal as predator densities diminish.

Protected status

Several of the mammal and bird predators covered in this review are legally protected in the UK, and there is little available published evidence on the effectiveness of removing these species for the purposes of lessening their predatory impact. Spatial and temporal variation in the distribution and breeding success of protected birds of prey in relation to some types of game management strongly suggest that illegal killing is capable of greatly reducing densities of raptors. However, there is a lack of

systematically collected information on the effects of such predator population control on prey populations. This review is, therefore, restricted to management of predators that can be legally removed.

Control of corvids and gulls

Removal of crows is typically carried out as part of a suite of predator control activities aimed at reducing the abundance and impact of several predator species. However, some mixed species removal programmes where abundance of crows was more strongly affected than that of other predators have successfully increased gamebird breeding productivity. Other studies have found that removal of crows alone is less likely to be successful than removal of crows along with other generalist predators, possibly because of compensatory increases in predation by other species, and possibly because the impact of other predators, such as nocturnal mammals, may sometimes be underestimated prior to crow removal. Gull population control can also be unsuccessful in achieving population growth of target prey species, possibly due to compensatory increases in predation by remaining gulls, or increased immigration of gulls from surrounding areas. Read more on [corvid control](#) or [gull control](#)

Control of Red Fox

The culling of foxes is widespread in the UK to reduce predation on domestic livestock, poultry, reared and wild game, other wildlife, and the spread of disease. Many (though not all) studies report success in the reduction of fox populations at a local scale but it is not clear to what extent culling can impact on fox populations at a larger scale. The consensus (though not unanimous) view from studies is that culling foxes at the den during the breeding season is the most effective means of suppressing populations. Several studies have demonstrated positive effects of fox removal on prey species. However, the effectiveness of fox removal in increasing target prey populations may depend on the range of other predator species removed, and on movement behaviour of target prey. [Read more on control of Red Fox](#)

Control of rats

There is plentiful evidence that introduced rat populations can exert severely negative impacts on native bird populations. A large number of rat eradication projects, primarily on islands, have demonstrated positive responses of wildlife. However, a rat eradication project on the Scottish island of Canna did not lead to expected recovery of seabird populations, presumably because of other limiting factors. Because rat control typically involves the use of poisoned bait, vulnerability of non-target species can be an issue. [Read more on control of rats](#)

Control of mustelids

Stoats and Weasels are regularly killed either by trapping or shooting by gamekeepers to increase gamebird populations. Ferrets and Ferret/Polecat hybrids may also be legally killed without licence, and it is likely that many programmes of small mustelid control also kill unknown numbers of some legally protected species, such as Polecats. Most such programmes have little apparent effect on bird numbers, unless carried out alongside control of other predator populations.

Across Europe there are many control programmes to reduce the negative impact that introduced American Mink exert on populations of ground-nesting birds and other species. Several, including some

in Scotland, have successfully reduced or eradicated Mink populations, typically with positive outcomes for target bird populations. Such programmes typically require long-term control and monitoring to limit spread or prevent recolonisation due to the mobility of Mink and its ability to swim relatively long distances. [Read more on control of mustelids](#)

Mixed species control

In a management context, the majority of predator removal programmes target multiple species of predator. This is partly because multiple species can be targeted by the same predator control strategies, but also because the removal of one predator can lead to compensatory increases in predation by others (because of a reduction in intra-guild predation or competition between individual predator species).

Several well-designed experimental and correlative studies of mixed predator control in Scotland, the UK and Europe have demonstrated that these can successfully increase productivity and population size of ground-nesting bird populations – particularly waders and gamebirds. Such studies usually involve removal of the suite of predators that is typically controlled for game management. These invariably include Red Fox and corvids, but frequently also mustelids such as Stoats and Weasels. Some studies clearly show that the efficacy of predator control varies between different situations, suggesting that it depends on other factors such as suitability of habitat, availability of food, the potential for compensatory predation by non-controlled predator populations, and the densities of both predators and prey. However, such interactions are less well studied.

There is a relative paucity of research on the impacts of mixed predator control on other species. An experimental study in England found that positive responses of breeding songbird populations to mixed species predator control increased with the rigour and taxonomic breadth of control programmes, though changes to agricultural practices may have contributed to these responses. [Read more on mixed species control](#)

Predator exclusion

An alternative strategy to removing predators is preventing them from accessing target prey species, particularly during the breeding season. This is typically done either by erecting cages or fences around individual nests, or else fencing off larger areas around clusters of nests or around suitable habitat. Exclusion is usually more practicable for mammalian predators than for birds, though predation of Roseate Terns by gulls has been successfully prevented using artificial exclosures. Several studies have demonstrated that fences or nest cages can dramatically increase the breeding success and size of ground-nesting bird populations. Limitations of this strategy include the cost of material and time required to erect and maintain exclosures (particularly for electrified fences), the potential for increased predation by birds following exclusion of mammals, and the potential for exclusion structures (particularly cages) to impact negatively on survival or behaviour of parents or young of target prey species. [Read more on predator exclusion](#)

Diversionsary feeding

Diversionsary feeding of breeding Kestrels (on Little Terns) and Hen Harriers (on Red Grouse) has been shown to reduce their intake of target prey species, by experimental work carried out in a small number

of sites. However, in the case of Hen Harrier feeding, this did not translate into increased numbers of Red Grouse available for shooting, for a variety of possible reasons. The extent to which diversionary feeding could increase the productivity or survival of predators, thereby increasing their potential to impact on prey at other times of year, is not well understood. [Read more on diversionary feeding](#)

Other strategies to reduce predation

There is considerable interest in the possibility that ecosystem restoration, through the re-establishment of top predators or competitors, could play a role in mitigating impacts from native or non-native predators. There is some correlative evidence that Foxes, Otters and White-tailed Eagles may reduce densities or movement of American Mink, and that Pine Martens may have a similar effect on Grey Squirrel, but this needs to be interpreted with due caution.

Conditioned taste aversion relies on conditioning predators to avoid predating the eggs of some or all wild birds by treating real or model eggs with noxious chemicals. Several studies have demonstrated that aversion can be developed using artificial baits, but it has yet to be proven as a means of decreasing levels of predation experienced by wild birds.

Domestic cats may impact negatively on a wide variety of wildlife species through direct predation and, potentially, through behavioural modification in response to predation risk. However, many cat owners reject the evidence that cats are a threat to wildlife and oppose current potential mitigation strategies, including the use of bell collars. [Read more on other strategies for reducing predation](#)

HABITAT AND FOOD SUPPLY

Establishment and management of vegetation

Many farmland birds are limited by food availability. Management for increased food availability include mixed cropping, provision of winter wild bird crops and other winter foraging habitats, and management of field margins to increase breeding season food and nesting cover. In general, measures aimed at increasing the availability of food for birds over the winter have had positive results at site and landscape levels. The provision of food and cover in the breeding season has had more mixed results, but has proven effective for boosting populations of some declining species such as Corncrakes and Grey Partridges. One potential drawback of the tendency to focus management on field margins is that it can increase losses of eggs and chicks to predators.

The potential benefits of controlling grazing (or mowing) activity include reduced risks of nest destruction, disturbance and predation and increases in nesting cover and invertebrate food availability. Most of these benefits depend on maintenance of grazing or mowing at low or moderate levels, or on timing of these activities so that their impact on bird populations is minimised. These benefits have been demonstrated for gamebirds in upland habitats and for waders, mostly in wet grasslands. Control of deer grazing in woodlands has been shown to benefit understorey birds including several declining migrant species.

Reductions in pesticides and herbicides can benefit a wide range of farmland bird species, through increases in abundance of plant and invertebrate food, as well as impacts on nesting habitat. [Read more on vegetation management](#)

Other habitat alterations

One of the most widespread measures comprising agricultural improvement is increased drainage, and raising water levels can have positive effects on declining waders and other species. However, it is likely that there is a trade-off, at least in some circumstances, between positive effects of soil moisture on invertebrate and negative effects on invertebrate biomass. Providing patches of bare ground or unsown areas can benefit species such as Lapwing and Skylark.

Hedgerows can provide nesting habitat and food resources for many bird species, but may also be associated with higher rates of predation on birds and nests in open field habitats. Measures to create and restructure woodland habitats to benefit a range of woodland species include: creating coppice woods; increasing availability of scrub; new woodland and thicket stages; restructuring closed canopy woodland with species such as birch; and reversing woodland drainage. Collisions with deer fences around some woodlands and moorlands can cause mortality in Capercaillie, Black Grouse and Red Grouse, which can be mitigated by removing or marking fences. [Read more on other habitat alteration](#)

Food provision

Supplementary feeding of predators is likely to increase predator populations under some circumstances. There is evidence that direct provision of winter food can benefit farmland birds, and songbird abundance is positively associated with woodland and farmland where winter food is provided for lowland gamebirds. Supplementary feeding of songbirds in gardens over winter can increase productivity of birds in subsequent breeding seasons, and in woodland experiments has led to increases in breeding density of Great and Blue Tits. Direct provisioning of gamebirds to increase numbers (or stem declines) has met with variable success, depending principally on whether food was the main limiting factor constraining population growth rates. [Read more on food provision](#)

COMBINED MANAGEMENT

Agri-environmental schemes

Few agri-environmental schemes (AES) have been adequately monitored and assessed. The available evidence suggests that effects of AES vary between species, schemes and regions, but that they can have positive impacts, particularly for seed-eating birds. Many of the management options for habitat, food supply and vegetation discussed above have had positive impacts on birds when implemented under AES-type schemes. These include reduced hedge cutting, grazing and chemical inputs, planting of food and cover crops, maintenance of wet field conditions, and delayed mowing. However, although AES schemes in the UK have been shown to benefit declining birds such as Corn Bunting, Yellowhammer, Starling, Grey Partridge and several species of wader, the extent of these benefits has typically been too small to reverse population declines. Also, several species do not appear to benefit appreciably from

targeted AES measures, and there is clearly scope for more thorough evaluation of AES in order to identify how best to make them more effective. [Read more on agri-environmental schemes](#)

Lowland game management

Multiple types of management have routinely been carried out to increase Grey Partridge and Pheasant populations. A combination of nesting habitat provision, predator control and ensuring sufficient insect food for chicks or supplementary feeding has been shown to be very effective in increasing Grey Partridge populations. Similar management for Pheasants has benefitted songbirds. [Read more on lowland game management](#)

Moorland game management

For more information on predator control, which is an integral component of moorland game management, see the earlier section on [Predation management](#) and, in particular, the sub-section on [Mixed species control](#). As well as predator control, management to provide Red Grouse for shooting generally includes habitat management actions, such as control of grazing intensity, and prescribed burning to maintain heather-dominated habitat. As these management activities are carried out together, the effects of individual activities can be difficult to infer from observational studies. However, several studies, using both experimental and facultative approaches and looking at variation in management over space or time, have shown that this type of management can benefit several species of ground-nesting birds. Experimental work has clearly shown the benefit of predator control for waders and gamebirds within this context. Benefits of moorland management for passerines have been inconsistent from one study to another, with some studies even finding that aspects of such management can impact negatively on species like Meadow Pipit, Skylark and Whinchat. This is likely to be because of the influence that repeated burning can have on the structure and composition of vegetation. Some elements of peatland vegetation that are suppressed by burning, such as scrub, grasses and *Sphagnum* mosses, provide food or cover for some birds. Several studies also suggest that this type of management is associated, in some parts of Scotland, with intensities of illegal raptor control that are sufficient to limit the populations of several species of raptors, including Hen Harriers, Peregrines and Golden Eagles. The findings of one study in the south-west of Scotland, where a comprehensive programme of moorland management failed to yield benefits for several species of wader and upland songbird, suggest that success of management programmes may depend on the influence of surrounding land uses on, for example, predation pressure. [Read more on moorland game management here.](#)

6.2 Stakeholder definitions of ‘healthy populations’

In order to discuss feasible conservation-management options with stakeholders, it was first necessary to explore shared management goals and understand how stakeholders defined “healthy populations” of predator and prey species in upland and lowland systems in Scotland.

The definitions given for healthy populations varied between Local and Scientific knowledge groups according to their land management objectives. The most common aim amongst both knowledge

groups was to achieve an overall balance and/or sustainability of both predator and prey populations allowing for fluctuating populations of both but stability over the longer term. However, ideas of balance and sustainability also varied between the groups, reflecting their management objectives. Both groups aimed to promote or maintain prey populations but Local Knowledge respondents more frequently thought this could be achieved by controlling predators while Scientific Knowledge respondents thought that current conservation strategies could be made more effective by limiting some human behaviours. Seminar participants acknowledged that different stakeholders have different objectives regarding desired numbers of predator and prey species and that it may be important to accept that concepts of healthy populations in localised areas may differ accordingly and that tipping the balance towards predators or prey may be acceptable as long as this does not result in unacceptably low numbers of any particular species. [Read more about stakeholder definitions of ‘healthy populations’ here.](#)

6.3 Stakeholder understanding of effectiveness of management options

Stakeholder groups varied in their opinions of which conservation-management technique they considered to be most effective. The Local Knowledge group favoured directly reducing predator numbers (predator control), whereas the Scientific Knowledge group favoured habitat management. However, participants from all workshop groups agreed that appropriate habitat and habitat management practices are vital for ground-nesting bird species to prosper. Preferences related to differing attitudes regarding proximate threats to ground-nesting birds and associated management objectives. Those who saw predators as the most immediate threat prioritised localised predator control since an urgent problem requires a fast-acting solution and reducing predator numbers has been proven to benefit numerous species, not only those prioritised as important. Those who viewed human activities as the most important threats prioritised improving habitat quality across the landscape as their long-term goal. They mainly discussed conservation-management in the context of addressing socio-ecological issues and expressed views about holistic restoration of complex ecosystems and landscapes to their ‘natural’ levels, although there was a lack of consensus about what natural levels might be.

However, teasing out the effects of other management techniques was perceived as more difficult and more long-term compared with predator control. Habitat management was also perceived as sometimes needing more widespread cooperation than predator control. It appeared that local knowledge holders may have more and longer-term experience of predator control than other management techniques, building confidence in predator control. A range of other forms of predator and habitat management techniques and their potential benefits were discussed to varying degrees, as were intra-guild predation, reintroduction, rewilding and agri-environmental schemes. [Read more about stakeholder understanding of the effectiveness of different management options here](#)

6.4 Effectiveness of management options – comparison of natural science findings and stakeholder knowledge

Of the 49 scientific studies considered, a greater proportion have considered the effectiveness of predator control (51%) and habitat management (57%) than have considered other forms of predator management (4%) (Figure 6a). Of the studies that considered predator management, 80% found it be effective at least some of the time, while the equivalent figures for habitat management and other forms of predator management are 86% and 50% (Figure 6a).

Among the Local Knowledge respondents who rated any forms of management, the proportions who rated predator control, habitat management and other forms of predator management were 90%, 81% and 58%, respectively (Figure 6b). Of these, the proportions who rated the techniques as being effective at least some of the time were 97% for predation, 94% for habitat management, and 72% for other forms of predator control.

Among the Scientific Knowledge respondents who rated any forms of management, the proportions who rated any forms of management who rated predator control, habitat management and other forms of predator management were 84%, 72% and 69%, respectively (Figure 6c). Of these, the proportions who rated the techniques as being effective at least some of the time were 83% for predation, 97% for habitat management, and 83% for other forms of predator control.

A higher proportion of respondents than studies considered the efficacy of each kind of technique. Similar proportions of studies considered both predator control and habitat management to be effective or sometimes effective.

Similar proportions of both the Local and Scientific Knowledge groups considered habitat management to be effective whereas the Local Knowledge group far more frequently supported predator control than the Scientific Knowledge group. Both groups acknowledged that the efficacy of habitat management was more likely to depend on the particular circumstances in which this technique is applied. In contrast, there was greater certainty within the Local Knowledge group that predator control is effective in most circumstances than within the Scientific Knowledge group, perhaps due to greater experience with this technique among Local Knowledge holders. [Read more here](#)

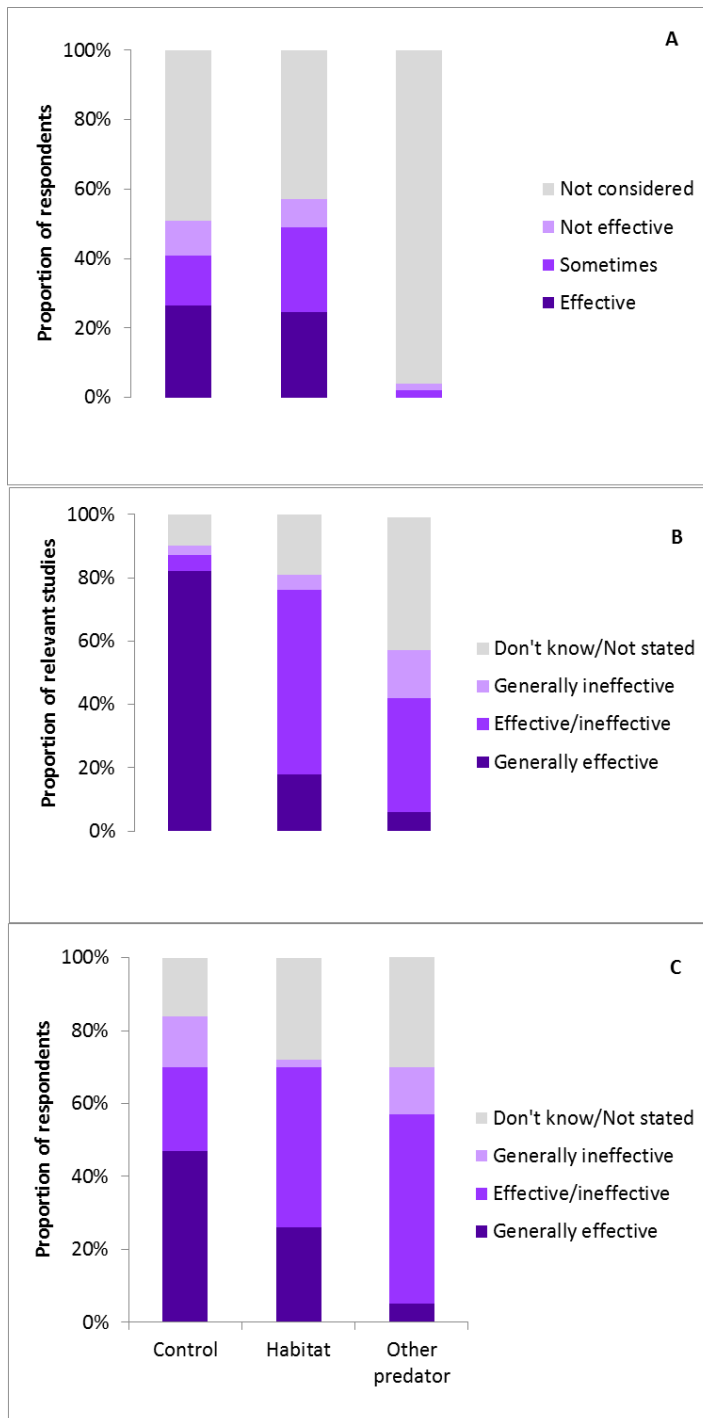


Figure 6. Comparison of findings from the natural science reviewing (A), Local Knowledge respondents (B) and Scientific Knowledge respondents (C) regarding effectiveness or otherwise of a range of conservation-management techniques. For the scientific reviewing, 49 separate scientific studies that considered the influence of management on gamebirds or waders were categorised for each management type as either 'effective', 'sometimes effective' or 'ineffective'. For the Local and Scientific Knowledge groups (n= 274), respondents rated conservation-management techniques for which they had understanding or direct experience as either 'generally effective', 'sometimes effective/sometimes ineffective', 'generally ineffective' or 'Don't know'.

7. FUTURE ACTIONS AND PRIORITY KNOWLEDGE GAPS

From the outset, this project did not seek to review the topics in order to identify research gaps and recommend future research for research's sake. Rather, the agreed objective was to focus on significant gaps in knowledge that currently prevent the community of interest from moving forward and limit management decisions.

7.1 Future collaborative actions

Many attendees at the Understanding Predation Project Review Seminars noted that the project had been a success in bringing the various interest groups together and providing them with opportunities to discuss the issues surrounding the declines of ground-nesting birds in Scotland and the role of predation in those declines. There was a shared aspiration amongst many attendees to find ways of maintaining this positive dialogue, and opportunities to work together through future collaborative actions. These future actions need not be research projects and some stakeholders expressed the need for urgent action to arrest population declines of the focal species rather than delaying to allow further research.

Collaborative actions can have several aims, which may include generating valuable information, and disseminating existing knowledge and understanding, as well as bringing together individuals and groups to work with one another. However, it is this latter element that is especially critical to continuing the positive interactions between the differing groups of stakeholders that have been an integral part of this project. In this section of the report, we endeavour to identify activities that can bring together people from different backgrounds, and with different knowledge, values and priorities, to engage in activities that allow them to share some common ground. These activities should enable participants to grow more familiar with one another, and to develop a mutual appreciation and respect for the perspectives of others. They will not make entrenched differences disappear overnight, but make it more likely that contentious issues will be given serious thought by all parties, and that compromises might be found that, ultimately, allow more effective conservation of ground-nesting wild birds in Scotland.

Methods

A list of ideas for future action was compiled based on responses to the online questionnaire, discussions during the Project Workshops, during the three Review Seminars and suggestions from the Project Steering Group, Review Panel and external referees from GWCT, JHI and RSPB during the reviewing of the draft report. The aim was to discuss the list of ideas further with stakeholders at a final additional Review Seminar but unfortunately this was not able to go ahead. To give interested stakeholders a chance to comment on the range of ideas and their merits further, the Research Group collated them into 29 possible future collaborative actions (Table A) and asked stakeholders to assess these in a short survey. These included:

- 8 actions aimed principally at fostering collaboration among the diverse groups of stakeholders with which the project has engaged;

- 16 actions aimed at addressing significant gaps in knowledge relevant to the ecology and management of wild birds; and
- 5 actions aimed at improving understanding of attitudes and values among the relevant community.

Many of these actions might contribute to multiple objectives if they were able to address one or more knowledge gaps or areas where understanding currently differs, at the same time as building trust through increased opportunities for dialogue and for working together, from design to delivery of these projects.

The survey was prefaced by a short introduction, some brief instructions, and an overview of the 29 ideas that required rating. Participants were asked to rate each of 29 ideas against five different criteria:

- Opportunity for collaboration across a broad range of stakeholders
- Likely acceptability across a broad range of stakeholders
- Opportunity to build greater trust between sectors
- Opportunity to provide new insights and fill key gaps in current knowledge
- Level of priority / interest for the participant or their organisation

Participants were asked to rate each idea against all five criteria as 'High', 'Medium' or 'Low', responding 'Don't know' if they were not certain. They were given the opportunity to record up to three additional ideas for collaborative actions that they thought were important, but were not among the 29 ideas we had asked them to rate. Participants were also asked not to circulate the survey for others to fill in, in order to restrict participation to a pre-defined group of people who had all been involved in the project. These included the participants in all the three project seminars, the Steering Group, the review panel and expert reviewers of the draft report. This ensured that the survey was assessed by a wide and representative cross-section of stakeholders. For a list of stakeholder participant affiliations see Table 16 in the Supplementary Material.

Survey assessments were numerically weighted to derive scores for each idea against each of the five criteria. Ratings of 'High' contributed a score of 2, 'Medium' a score of 1, and 'Low' a score of 0, with ratings of 'Don't know' not being included. The average score for each criterion provides an overall assessment across all survey participants, with scores close to 2 indicating consistently high ratings, and scores close to 0 indicating consistently low ratings. For each action, these scores are summed to give an overall score out of 10. These scores should not be interpreted as exact measures of project quality, but as indications of the relative value of and support for each project among the stakeholder community. The actions are ordered by rank according to this overall score in Table C.

Table A. Short descriptions of the 29 future collaborative actions presented to stakeholders for assessment by survey in the Understanding Predation project. The ideas are grouped under three headings (Fostering Collaboration, Ecology & Management, and Attitudes & Values) according to their primary aims and foci, but many of these ideas could contribute to multiple collaborative objectives. The full description of each idea provided in the survey can be found in [Table 15](#) in the Supplementary Material.

Fostering collaboration (FC)	
FC1	Adaptive management forum
FC2	Stakeholder meetings
FC3	Standing in another person's shoes
FC4	"High-tech, web-based portal"
FC5	Citizen science projects
FC6	BASC Green Shoots mapping initiative
FC7	Improved links between monitoring and public awareness / education
FC8	Large-scale demonstration sites
Collaborative projects - management and ecology (ME)	
ME9	Causes of curlew decline
ME10	Recruitment and dispersal of black grouse
ME11	Impact of legal predator removal on success of ground-nesting birds
ME12	Impact of protected species removal on success of ground-nesting birds
ME13	Predation and predator activity
ME14	Scale of predation impacts
ME15	Interactions between predator control and habitat management
ME16	Influence of land use and landscape configuration on generalist predator activity
ME17	Effects of human-mediated food availability on predator activity
ME18	Costs and benefits of different models of land use
ME19	Effects of disturbance on ground-nesting birds
ME20	Consequences of spatial pattern in predator removal
ME21	Societal benefits of economically non-productive land
ME22	Intra-guild predation in raptors
ME23	Predator removal and compensation between predators
ME24	Effectiveness of different predator control techniques
Collaborative projects - attitudes and values (AV)	
AV25	How do stakeholder attitudes and values regarding predation influence conservation?
AV26	What are public attitudes to predation impacts on ground-nesting birds?
AV27	Building a shared vision for the countryside
AV28	Understanding constraints to licenced control of some protected predators
AV29	Enhancing predation management through the SRDP

Results

The survey was completed by 35 participants representing a wide cross section of stakeholders (Table 16).

Of the eight actions for fostering collaboration, the two scoring highest overall were action 1, involving the establishment of an adaptive management forum, and action 8, establishing one or more large demonstration projects (Table C). Action 1 was rated very positively by stakeholders in terms of opportunities for collaboration, building trust, and individual prioritisation. Its lower rating for insight need not be a concern if the aim of such a project was primarily to foster good relations (though such a forum, if well managed, could be used to improve the evidence base on which decisions about management practice could be based). Action 8 was rated higher for insight, but lower for acceptability and priority. Several stakeholders commented that previous, similarly large projects, such as Langholm, had proved very expensive, but had delivered little in terms of resolving disagreements and conflicts.

The highest scores for the 16 ecology and management actions went to actions 9, 10 and 13, placing these actions in the top ten in almost all categories (Table C). These are field-based projects, the first two of which are aimed at collecting more information on population drivers of Curlew and Black Grouse, respectively, and the third of which is aimed at collecting more information on predator activity. This kind of project could provide valuable opportunities for stakeholders to accumulate shared experiences and evidence relating to wild birds and their environment, contributing to the development of mutual trust and respect. The involvement of different stakeholders in the design, implementation and reporting of such studies does not preclude differences in interpretation, but it does make it more likely that agreement can be reached on what the data do and do not show. As well as providing stakeholders an opportunity to engage with one another and build up a shared body of experience and evidence, these projects also provide information that is valuable for conservation, of interest to a wide cross-section of stakeholders.

The highest overall score given to any of the 5 attitudes and values actions went to action 25, exploring and increasing societal awareness of stakeholder attitudes towards different predator species and the impact of predation (Table C). Ratings for this action were in the top 10 for all 5 criteria, indicating that many stakeholders believed that this action would not just be good for promoting collaboration, but had the potential to yield useful insights and to advance the interests of their sectors. During this project, many stakeholders expressed the belief that lack of understanding of predation among the public was one of the most significant barriers to legislative and regulatory change to enable better management of predators. The phrase “better management” would definitely mean different things to different stakeholders but, nevertheless, better and wider understanding of the values and attitudes of stakeholders would be a positive development.

In order to be successful in engaging stakeholders, projects should ideally have a focus that is of immediate interest to them, and a remit that does not directly threaten their positions. For example, projects looking at the ecological effects of non-native game bird releases (e.g. action 17) or investigating the effect of removal of protected raptor species on breeding success of ground-nesting birds (e.g. action 12) could yield information that would support a case for societal change. Such change might be welcomed by some stakeholders, and have positive consequences for society

or wild bird conservation in the long run, but could also be perceived as threatening the interests or livelihoods of others. This could make it more difficult to successfully engender collaboration through such projects than through those aimed at generating information that all parties welcome and recognise the need for.

Table C. Average scores against each of five criteria (opportunity for collaboration across a broad range of stakeholders; likely acceptability across a broad range of stakeholders; opportunity to build greater trust between sectors; opportunity to provide new insights and fill key gaps in current knowledge; and level of priority / interest for the participant or their organisation) for 29 ideas relating to future collaborative actions, rated by 35 stakeholders who participated in an online survey. Participants gave each project a rating of ‘High’ (score = 2), ‘Medium’ (score = 1), ‘Low’ (score = 0) or ‘Don’t know’ (no score) against all five criteria. The top 10 scores under each criterion are shaded the same colour as the column header. For each project, average scores for each criterion, an overall score (from 0 to 10) combining scores for all five criteria, and a rank based on this score, are given in the table below. Projects are ordered by rank.

Action	Collaboration	Acceptability	Trust	Insight	Priority	OVERALL	Rank
ME13	1.69	1.35	1.43	1.77	1.76	6.24	1
ME10	1.63	1.51	1.34	1.69	1.58	6.17	2
ME9	1.66	1.38	1.27	1.74	1.58	6.06	3
ME20	1.62	1.13	1.40	1.74	1.64	5.89	4
AV25	1.58	1.26	1.36	1.64	1.48	5.83	5
ME22	1.59	1.22	1.33	1.67	1.41	5.81	6
ME19	1.49	1.23	1.37	1.71	1.45	5.80	7
ME15	1.59	1.20	1.37	1.60	1.36	5.76	8
FC8	1.65	1.06	1.41	1.57	1.48	5.69	9
ME18	1.54	1.18	1.34	1.60	1.52	5.66	10
FC1	1.69	1.15	1.38	1.33	1.61	5.55	11
ME23	1.52	0.97	1.30	1.71	1.52	5.50	12
AV27	1.46	1.26	1.29	1.49	1.42	5.49	13
ME14	1.55	0.97	1.24	1.71	1.48	5.46	14
AV29	1.53	1.09	1.32	1.47	1.53	5.41	15
ME16	1.45	1.21	1.24	1.47	1.34	5.38	16
FC2	1.57	1.09	1.23	1.43	1.48	5.32	17
ME11	1.47	1.06	1.32	1.31	1.30	5.17	18
ME21	1.39	1.23	1.06	1.45	1.23	5.13	19
FC7	1.42	1.30	1.21	1.06	1.42	5.00	20
AV26	1.26	1.09	1.11	1.46	1.36	4.92	21
FC6	1.31	1.23	1.16	1.21	1.34	4.91	22
FC3	1.49	1.00	1.18	1.18	1.09	4.84	23
ME12	1.40	0.44	1.18	1.71	1.52	4.73	24
AV28	1.31	0.62	1.17	1.60	1.48	4.70	25
FC5	1.38	1.03	1.12	1.11	1.12	4.64	26
ME24	1.26	0.71	1.14	1.51	1.27	4.62	27
ME17	1.06	0.87	0.94	1.27	1.03	4.14	28
FC4	1.17	0.91	0.85	1.09	1.03	4.01	29

This is not to say that controversial projects are unimportant, nor that projects aimed primarily at filling knowledge gaps should necessarily be recognised as important by all stakeholders before they are carried out. Some other ideas for action that do not feature prominently in the ratings of the stakeholders could nevertheless make valuable contributions to stakeholder understanding of the issues dealt with by this project. These include actions 11, 16 and 17, which involve research on the ways that predator abundance and predation impacts are affected by legal predator control, human-managed landscapes, and human-mediated food sources. All of these projects could fill important gaps in currently available information on predation (in the case of projects looking at legal predator control, confirming and clarifying when and where effects that have been clearly demonstrated in a few studies apply in a wider variety of contexts), but were not recognised as being well-suited to encouraging collaborative action by the majority of stakeholders. Other projects, such as action 22 looking at the consequences of intra-guild effects for predator and prey assemblages, and action 23 on compensatory predation following removal of a subset of predators, were recognised by project stakeholders as having the potential to yield useful information, but were rated less positively in terms of respondent priorities (intra-guild predation) and potential for collaboration (compensatory predation).

Two other projects that were very positively rated, ranking in the top ten under four of the five criteria, were action 20 (Table A) looking at the consequences of spatial pattern of predator removal, and action 25 (Table A) exploring stakeholder values and attitudes towards different predator species. The first of these could have a strong, field-based component, though to generate the anticipated information it would have to be coordinated and synthesised at a large spatial scale. Nevertheless, it could also provide ample opportunity for stakeholders to work together on the ground, and (like actions 9, 10 and 13) could also help to build trust and relationships at higher levels of participating organisations through collaboration during design, coordination, analysis and reporting.

One final consideration concerns the investment of time that is required to develop true collaborations and foster continuing trust between different stakeholder interests. Many of the future actions identified as higher priority by stakeholders would constitute projects of fixed duration, and would not necessarily result in a step change in collaboration and trust that would be maintained in the longer-term. Possible future initiatives like actions 1 (adaptive management forum), 5 and 6 (with potential to develop wider stakeholder involvement in longer-term data collection and monitoring) would serve to increase collaboration and trust over longer timescales and could lead to greater overall ownership of the basic monitoring information on which a whole range of conservation-management decisions are, or will be, based.

7.2 Priority knowledge gaps

During the course of the project, knowledge gaps in both the natural science literature and the social science understanding were documented by the Research Group. Whilst the project concludes that placing focus on future collaborative actions, rather than research per se, is very important, future actions that serve to fill some of these priority knowledge gaps could be seen as delivering multiple benefits. We did not formally prioritise gaps in knowledge, but have considered how addressing these gaps could inform the management and conservation of wild bird populations. Finding out

more about the size, movements and ecological impacts of the non-breeding components of predator populations, and the impacts of protected predator species, would yield information that could directly inform predator management (or contribute to decisions about how best to achieve this). The latter research topic would be a particularly valuable one to fill, but some experimental approaches that would otherwise be well suited to achieving this are likely to be controversial and could prove divisive. The findings of research on the ecological consequences of intra-guild interactions between different predator species, or of gamebird releases and other human sources of food for generalist predators, has the potential to change attitudes among those responsible for management of wild birds. Projects aimed at filling several other knowledge gaps, such as those concerning interactions between habitat and predation, trends and drivers of predator populations, and non-lethal predator management techniques, could fulfil multiple roles. As well as allowing more effective management of wild bird populations, such projects could also help to dissipate conflicts, both by informing management options that are acceptable to a wide range of stakeholders, and by providing opportunities for different groups to collaborate in organising and carrying out these projects. [Read more on knowledge gaps here.](#)

8. DISCUSSION

8.1 Novelty of project approach

This project brought together a broad range of stakeholders, policy advisers and scientists with varied interests in wildlife management and conservation to discuss the issues around predator-prey interactions, highlight the commonalities and differences in understanding between sectors, and identify potential future collaborative actions and priority knowledge gaps. The approach was novel and challenging for two reasons. First, it sought to directly compare and contrast findings from the published literature with the understanding of stakeholders interested in Scottish wildlife, conservation, countryside and management. Some stakeholders relied primarily on science and the findings of research projects, others on their personal experiences and discussion with peers, and many on a combination of knowledge forms. Contrasting different forms of knowledge in this way is rarely done. The mandate for this approach came from the project funders, the members of the Moorland Forum, and lead members of the research group that delivered the previous (2005) review commissioned by the Forum. They collectively did not recommend a repeat of the 2005 scientific report because the latter was not considered to have been widely used by policy and practice stakeholders. As such, the integration of local knowledge, through a process involving diverse members of the stakeholder community, was seen by many groups of the Moorland Forum to be preferable in order to achieve a more holistic understanding of the drivers of population change of wild birds in Scotland, and to identify areas of agreement where joint action could be taken. The second novel aspect was that the stakeholders involved varied widely in their objectives and views on the principal drivers of wild bird population change, leading to adversarial positions being adopted not infrequently. Here our approach was to encourage the sharing and exploration of different perspectives, highlight areas of agreement and disagreement, and explore possible shared actions to address any differences and key gaps in knowledge.

Scientific and local forms of knowledge both have their strengths and their weaknesses. Science, when done well, can provide clear, objective information to help guide management decisions, but the spatial and temporal scales at which studies are implemented may not always be those that are appropriate to stakeholders or the specific questions that require answering to make management decisions. Necessarily, science is often reductionist and may therefore lack the broader context. It may also be perceived by some as biased, because of those who carry it out or fund it, or as hindering more immediate decision-making and management action. In contrast, local knowledge provides direct experience in the wider, on-the-ground context, but usually without the more rigorous data collection structure that robust science generally implements. Because both these forms of knowledge can be open to bias, the data, study design and methods of data collection need to be considered critically when interpreting the results. There are powerful arguments for bringing these different forms of knowledge together to critically appraise the information, develop an agreed evidence base and address the weaknesses on both sides through the co-production of knowledge. Following this premise, the project started from a position that critically assessed both published science and local knowledge, and did not assume that either was 'the correct answer'.

8.2 Commonalities and differences in understanding between stakeholder groups and the scientific literature

There was a great deal of agreement between the natural science review findings and stakeholder understanding. This is perhaps due to the way that knowledge is developed and shared, for example many scientists and practitioners relied on both local observations and scientific evidence to varying degrees. These considerable areas of consensus should form solid foundations from which to progress discussions, address differences and move towards shared solutions.

The availability for the first time of comprehensive data on the changes in abundance during the breeding season for a whole range of bird species that could be assessed at regional and even finer scale provided this project with a novel opportunity to compare these changes with local stakeholder knowledge in specific geographical areas. There was common agreement amongst project participants that the six prey species that were the focus of stakeholder discussions had decreased and that three of the four predators had increased. The Local Knowledge group, however, considered that predators had increased more than did the Scientific Knowledge group. The main suggestion given for this difference was related to differences in the geographical scale of knowledge between the groups. The starkest difference between Local Knowledge understanding and the Atlas data was related to crows, with the former group considering that crows had increased, whereas the data from the Atlas was more equivocal. The arguments around changes in abundance highlight the validity of considering both forms of knowledge, provided that both are critically appraised. Local knowledge and experience of changes in abundance for some species may be at a finer scale than detectable through Atlas data or local knowledge may relate to a component of the bird population that the Atlas survey was not designed to measure.

Stakeholders were also in general agreement over the relative order of importance of the main factors thought to be responsible for population trends in these prey species. However, there were two principal differences. The Local Knowledge group considered predation to be the most important factor, whilst the Scientific Knowledge group considered habitat to be most important.

One reason for this is that predation is more obvious and immediate and the benefits of predator control are apparent in many cases. In contrast, whilst the science may suggest that habitat management is important, its benefits may require management over a larger spatial scale and a longer time scale. This means that some stakeholders may consider habitat management less within their immediate ability to take action with any urgency. Some also feel that they have already maximised appropriate beneficial habitat management on their land. These differences also emerged in relation to the relative effectiveness of predator control and habitat management. There is clearly a strong division amongst stakeholders between those who focus on predators and those who focus on habitat, suggesting the importance of this area for future work – what is the relative importance of these two drivers and how do they interact – that is, does the importance of predation as a force driving change in prey populations vary depending on the type of habitat and the way it is managed? If the habitat is appropriate, is predator control required?

Due to the highly managed, fragmented nature of the Scottish landscape, conserving ground-nesting wild birds was seen by many local and scientific knowledge participants as very complex. Habitat loss and land-use change were identified as major drivers of population change for both predator and prey species, and habitat quality and predation were often described as interlinked. Therefore, appropriate habitat management and predator control strategies were considered by many to be very important for achieving healthy populations of both predators and prey.

This disagreement was reflected in discussions over what constitutes “balance” and how to achieve “healthy populations”. Those who preferred local knowledge tended to focus on prey populations and predator control, whilst those favouring scientific knowledge focused more on promoting prey through limiting the impact of environmental, notably habitat, or human factors. Discussions highlighted an ideological difference in attitudes held by participants from the hunting/shooting community and those from the conservation community about what ideal habitat for ground-nesting birds should look like, and what composition of species diversity and population sizes such habitat should support. This may partly characterise the disagreement between these communities about the need for increased predator control measures; participants viewed this need as symptomatic of the desire among members of the hunting/shooting community for artificially high populations of gamebird species whereas many local knowledge participants were frustrated by the perceived lack of public and political support for the kinds of conservation-management strategies they see as essential for preventing the extinction of some ground-nesting bird species in Scotland.

8.3 Challenges, constraints and achievements

Inclusive approaches that fully involve stakeholders in all stages of a project from inception to delivery can be time intensive to implement effectively. Time limitations in this project necessitated that the natural science literature reviewing and population trends analytical work were carried out concurrently with evidence collection from stakeholders. This meant that the formulation of questions in the questionnaire survey and workshops could not be informed by the detailed findings of the natural science work, and this led to some difficulties with comparing the findings directly. We consider that delivery of the natural science reviewing and analysis as a discrete first step would have informed the stakeholder engagement work more effectively and allowed a more in-depth approach to examining commonalities and differences.

We undertook to carry out the major part of the natural science evidence collection using a formal systematic reviewing approach, which required the selection of both objective literature searching terms and selection criteria by which to filter evidence for inclusion. This approach acknowledges that not all published science is necessarily impartial, for example because selective inclusion of material can occur in some reviews. It also recognises that previous reviews on similar topics may have had a slightly different scope and then would not adequately answer the specific remit of the current project. One disadvantage of this approach is that it is time intensive because it necessitates reading and filtering very large numbers of primary literature publications against the objective criteria. This meant that a large proportion of the project time available for the natural science work had to be spent on this reviewing, and less than anticipated on novel analyses of Scottish population trend information. The time available also dictated that much of the reviewing and synthesis had to be focussed on peer-reviewed papers, as a fully comparable review of grey literature (e.g. via systematic web-based searching) was not possible within the resources. We were reliant on stakeholder involvement to direct us to further grey literature to include. On balance, although the systematic reviewing approach has many merits for a review tightly focussed on one narrow topic, we would not recommend the approach for a review of this breadth in future. Rather, we consider that commissioning independent and strictly impartial researchers to carry out such reviews using traditional methods is adequate and effective.

The short timeline of the project also meant that we could not follow as robust an approach to some of the social science elements as we would have liked. It would have been beneficial to have had more time to fully analyse the stakeholder questionnaire data before running the workshops and seminars, to highlight and discuss all areas of agreement and divergence between the knowledge groups, and between the knowledge groups and the scientific literature in more detail.

Some members of the stakeholder community and some research participants raised concerns about the design of the project. Some considered that the project focussed too much on the negative impacts of predation, rather than broader ecosystem / landscape processes. Whilst we accept that these are interesting and important issues, they were beyond the scope of this project, which focussed on predation. Others considered that some of the questions about predators were leading, and that the research group was biased. We attempted to balance our questions to align with the design of the natural science review, the initial pilots of the questionnaire did not raise any concerns, and we engaged in an intensive and iterative process with the project Steering Group to minimise bias in all stages of our research.

There was a high level of stakeholder participation in the project, especially amongst those with game management interests and those involved with the bird conservation NGOs. In this 12 month project, 400 questionnaires were completed by stakeholders from 70 organisations, representatives from 15 of these organisations participated in nine workshops and over 100 representatives contributed to three Review Seminars. At the Seminars, many expressed a view that the project had been useful in bringing together a broad range of stakeholders and successfully increasing dialogue about a range of sensitive subjects. The novel combination of scientific literature reviewing and collection of local knowledge from stakeholders, and the opportunity to highlight the many areas of agreement and explore areas of disagreement, were seen as useful and effective and most stakeholders appeared to feel genuinely involved and that their views were considered.

However, some sectors were not well represented, notably the farming community, and overall there was more participation from upland interests than from those in the lowlands. This was despite ongoing attempts to engage organisations representing farmers in early discussions relating to the project design and development. The farming sector is important in this debate given its great influence on the countryside and role in management for the selected focal wild bird prey species and it would be sensible to prioritise engaging the sector in any future work.

For this report, we categorised participants depending on whether they favoured local or scientific knowledge when learning about predation of upland and lowland ground-nesting birds, as we were keen to explore similarities and differences in views that may be influenced by these two forms of knowledge. However, we recognise that many individuals relied on both forms of knowledge to varying degrees. Also, there are different ways of categorising participants and even within these groups there are a diversity of interests and affiliations. It will be valuable to explore how responses vary across different sectors and organisations. Exploring the variation across these groupings would help highlight the challenges and opportunities in developing future actions.

Much of the support from local knowledge holders was based on trust. Trust develops through repeated interactions between parties and is an important driver of collaboration. It may reduce future conflict by building relationships through sharing of knowledge and values. Maintaining and building trust both during the process of this project, and subsequent to this project is therefore essential if conflicts around predation are to be addressed successfully.

A potential barrier we face in a project of this sort is the potential loss of trust if one knowledge group feel their expectations have not been met. Expectations could relate to their knowledge being adequately represented, or the identification of joint action on addressing issues associated with predation. It is therefore important to emphasise the high levels of agreement between the local and scientific knowledge holders on a number of aspects. For these areas, action should be taken to continue building on the momentum of collaboration, and to continue building trust between stakeholders.

On those areas where there is a difference between the understanding of local and scientific knowledge holders, a number of suggestions were made by participants on joint action (Section 7 above). Building on the process and outcomes of this project, we can perhaps hope to gradually move from local, specialised and strategic knowledge to integrative knowledge, which stresses the “mutual acceptance of an overarching framework, direction or purpose, derived from a shared interpretation of the issues”. [Read more about knowledge here](#)

8.4 Conclusions and the way forward?

So, what next? On the topic of future research, the view shared by many at the project seminars, is that we need to move away from the current model of science ignoring local knowledge and feeding directly into policy and instead we should be developing new collaborative approaches, challenging though they might be. We should be linking robust science together with local knowledge holders from the outset, in agreeing the questions, designing the research, collecting the data and interpreting the results. Such knowledge co-production is a way of overcoming the potential biases

and building new knowledge that is accepted on both sides, especially in those areas where there is disagreement. In addition to research, the divergent objectives around achieving “healthy populations” appeared at the heart of this project and will need to be discussed further to see if a common goal can be agreed and pursued. Maintaining the momentum on these shared challenges will be essential to keep all stakeholders engaged.

A further view expressed by some stakeholders is that we need to act now and evaluate and adapt our management as we go, otherwise we are “*fiddling whilst Rome burns*”. The view was expressed by some local knowledge users that we do not need yet more research that will further delay action. Whilst action is clearly needed to address the burning issues highlighted in the workshops and seminars, this has to be combined with a robust design so that we can monitor the effectiveness of actions, learn from the emerging evidence and adapt our management accordingly to improve future management. This is at the heart of adaptive management - to act, design experiments to test the effectiveness of that action, monitor the effects and adapt the management in a repeating cycle. Without the appropriate design, experiments and monitoring we will never know exactly how effective our actions are and how to improve them.

Another important area of future focus is to build on the experience of this project and bring the stakeholders, scientists and policy advisers together in a specific forum to examine the evidence, develop a shared understanding of the key issues and develop strategies and proposals for answering their uncertainties. If stakeholders are involved at the outset, and the different sectors and arguments are included in those discussions, then there is potential for all sides to buy into the findings and adapt according to the shared evidence.

One of the challenges of building such collaborations is that some sectors may feel less willing to engage because they are concerned about the focus, or the direction in which the collaboration is going. A concerted effort will be required to ensure that all voices are acknowledged, respected and listened to and that there is a trusted chair running the meetings who ensures that the parties all have a say. Equally important is ensuring that all parties are encouraged to take part in those discussions and encouraged to develop the work. Monitoring of the progress of such a forum will be required to constantly improve the process and outcomes of the forum’s work. Such monitoring should allow for pro-active recognition of whether parties want to pull out of the forum - genuine effort must be made to understand the reasons why parties may not be engaging in the forum, and genuine effort will be needed to address these reasons. If stakeholder groups are absent from the forum, it will be at risk of losing legitimacy. Over time, the above approach should help to build trust among and between stakeholder groups, thereby potentially reducing conflict.

UNDERSTANDING PREDATION – SUPPLEMENTARY MATERIAL

CONTENTS

1. HOW TO USE THIS SECTION	70
2. REVIEWING METHODS	71
2.1 Natural science research methods	71
2.1.1 ANALYSIS OF POPULATION TRENDS.....	71
2.1.2 OTHER PROJECT-SPECIFIC ANALYSES	77
2.1.3 FORMAL LITERATURE-SEARCHING METHODS	78
2.1.4 OTHER SOURCES OF INFORMATION FOR THE REVIEW	83
2.1.5 FORMAL SYSTEMATIC EVALUATION OF LITERATURE	84
2.2 Social science research methods	85
2.2.1 SAMPLING STRATEGY.....	86
2.2.2 QUESTIONNAIRE DESIGN	86
2.2.3 WORKSHOP PROGRAMME.....	87
2.2.4 SEMINAR PROGRAMME.....	87
2.3 Analyses	88
2.3.1 QUALITATIVE ANALYSIS - CODING	88
2.3.2 CLASSIFYING STAKEHOLDER GROUPS.....	88
2.3.3 COMPARISON ON KNOWLEDGE	90
2.3.4 UNCOVERING COMMONALITIES AND DIFFERENCES BETWEEN STAKEHOLDER KNOWLEDGE AND NATURAL SCIENCE REVIEWING	90
2.3.5 STATISTICAL ANALYSES	91
2.3.6 QUESTIONNAIRE PARTICIPANTS – CHARACTERISTICS OF THE SAMPLE	91
3. HOW DO STAKEHOLDERS GAIN AND USE KNOWLEDGE?	93
3.1 Ways in which stakeholders gain information.....	93
3.2 Use of knowledge to make assessments about drivers of population change	98
4. POPULATION TRENDS OF WILD BIRDS AND THEIR PREDATORS IN SCOTLAND	99
4.1 Review of population trends for mammal predators of wild birds	99

EUROPEAN HEDGEHOG	99
RED SQUIRREL	100
GREY SQUIRREL	101
COMMON RAT	102
SHIP RAT	102
RED FOX	103
PINE MARTEN.....	104
STOAT	104
WEASEL	105
POLECAT.....	105
FERAL FERRET.....	106
AMERICAN MINK.....	106
BADGER.....	107
OTTER.....	108
WILDCAT	108
FERAL / DOMESTIC CAT.....	109
4.1 Review of population trends for raptor predators of wild birds	110
RED KITE	110
WHITE-TAILED EAGLE.....	113
HEN HARRIER	115
GOSHAWK	118
SPARROWHAWK	120
COMMON BUZZARD	122
GOLDEN EAGLE	125
KESTREL.....	128
MERLIN.....	131
PEREGRINE	133
TAWNY OWL	138
SHORT-EARED OWL.....	140
4.3 Review of population trends for corvid predators of wild birds.....	142
MAGPIE	142
JAY	145
JACKDAW	147
CARRION & HOODED CROWS	150

RAVEN	153
4.4 Review of population trends for skua and gull predators of wild birds	156
ARCTIC SKUA	156
GREAT SKUA	158
BLACK-HEADED GULL	160
COMMON GULL	162
LESSER BLACK-BACKED GULL	164
HERRING GULL	166
GREAT BLACK-BACKED GULL.....	168
4.2 Review of population trends for wild bird prey: focal species	170
BLACK GROUSE.....	170
CURLEW	173
GOLDEN PLOVER	176
GREY PARTRIDGE	179
LAPWING.....	182
OYSTERCATCHER.....	185
4.3 Review of population trends for wild bird prey - other breeding wild birds.....	188
Changes in Scottish breeding bird populations since 1988-91	188
Changes in Scottish breeding gamebird populations since 1988-91	188
Changes in Scottish breeding wader populations since 1988-91	189
Changes in Scottish breeding bird of prey populations since 1988-91.....	189
Changes in Scottish breeding waterbird populations since 1988-91.....	189
Changes in Scottish breeding songbird and near passerine populations since 1988-91.....	189
Changes in Scottish breeding bird predator populations since 1988-91.....	190
Changes in Scottish breeding populations of birds on General Licences 1-3 since 1988-91.....	190
Comparison of changes between upland and lowland land types since 1988-91.....	190
Changes by Natural Heritage Zone of Scotland since 1988-91	190
4.4 Stakeholder perceptions of population trends for wild birds and their predators	203
4.4.1 Questionnaire results.....	203
4.4.2 Workshop results	203
4.5 Population trends of wild birds and their predators in Scotland – comparison of stakeholder knowledge and natural science findings.....	205
4.5.1 Questionnaire results.....	205
4.5.2 Workshop results	205

4.5.3 Seminar results	206
5. DRIVERS OF POPULATION CHANGE OF WILD BIRDS AND THEIR PREDATORS, INCLUDING THE ROLE OF PREDATION	208
5.1 Natural science review of drivers of population change for wild birds and their predators....	208
PREDATION	208
OTHER DRIVERS OF CHANGE	212
FOCAL SPECIES – BLACK GROUSE.....	218
FOCAL SPECIES - GREY PARTRIDGE	223
FOCAL SPECIES - LAPWING.....	226
FOCAL SPECIES - GOLDEN PLOVER.....	232
FOCAL SPECIES - OYSTERCATCHER.....	235
FOCAL SPECIES - CURLEW	237
UPLAND GAMEBIRDS	240
UPLAND WADERS.....	245
OTHER UPLAND BIRDS	246
LOWLAND GAMEBIRDS AND WILDFOWL	247
LOWLAND WADERS	248
OTHER LOWLAND BIRDS	250
RAPTORS AND CORVIDS.....	254
5.2 Stakeholder understanding of population drivers of wild birds and their predators.....	256
5.2.1 Environmental and human drivers of population change	256
5.2.2 Predator species perceived to drive population change (focal species)	268
6. CONSERVATION-MANAGEMENT OPTIONS.....	275
6.1 Natural science review of conservation-management options.....	275
PREDATOR MANAGEMENT	275
HABITAT AND FOOD SUPPLY.....	285
COMBINED MANAGEMENT	289
6.2 Stakeholder definitions of ‘healthy’ populations.....	293
6.2.1 Stakeholder Knowledge – definitions of ‘healthy’ populations.....	293
6.3 Stakeholder understanding of effectiveness of management options	295
6.3.1 Questionnaire results.....	295
6.3.2 Workshop results	300
6.3.3 Seminar results	311
6.4 Effectiveness of management options – comparison of natural science findings and stakeholder knowledge.....	311

6.4.1 Questionnaire results.....	311
6.4.2 Seminar results	314
7. GAPS IN UNDERSTANDING & FUTURE PRIORITIES.....	315
7.1 Knowledge gaps	315
7.2 Future collaborative actions	320
8. DISCUSSION	333
9. LITERATURE CITED.....	335
APPENDICES.....	336
Appendix 1: Questionnaire and workshop participants' organisational affiliation.....	337
Appendix 2: Online questionnaire	340
Appendix 3: Main topics of the online questionnaire	341
Appendix 4: Understanding Predation workshop timetable and participants.....	343
Appendix 5: Understanding Predation workshop guide.....	344
Appendix 6: Review seminar guides	347
Appendix 7: 'Other' most important forms of information.....	350
Appendix 8: Local and Scientific Knowledge group respondents' organisational associations.....	351
Appendix 9: Questionnaire respondents' socio-demographic information	352
Appendix 10: Organisational affiliation of questionnaire respondents.....	353
Appendix 11: Breeding distribution change at NHZ scale	355
Appendix 12: Definitions of 'healthy' populations of predators and prey	380
Appendix S1: Conservation status	382
Appendix S2: National population change.....	382
Appendix S3: NHZ abundance change	382
Appendix S4: Abundance change by land type.....	382

1. HOW TO USE THIS SECTION

This section contains in-depth material, and is aimed at those who want to find out more about the topics dealt with in the Main Report, above. We anticipate that this section will be particularly useful for:

- Those wanting more detail about the methods used during this project.
- Those wanting to access detailed information about population trends of wild birds in Scotland, contained in Section 4.
- Those wanting to access detailed information about population drivers and management techniques, including details of the source literature reviewed, in Sections 5 and 6.
- Those wanting to access detailed information about stakeholder knowledge and understanding captured during stakeholder workshops, seminars and extracted from analysis of questionnaire responses.

Online readers can use the hyperlinks in the Main Report to take them straight to the relevant detail in the Supplementary Material. For hard-copy users of the report, or those who wish to read the Supplementary Material more extensively, the sections have been organised in the same order, and under similar headings, as those used in the Main Report.

2. REVIEWING METHODS

2.1 Natural science research methods

2.1.1 ANALYSIS OF POPULATION TRENDS

The current review aimed to synthesize data and published science, and include a new Scottish and regional analysis of recent changes in wild bird populations based on *Bird Atlas 2007-11* information (Balmer *et al.* 2013), integrating the findings with updated results from other long-term monitoring schemes and periodic surveys since the Park *et al.* (2005) review. The review explores recent (post 1960) population trends in wild bird prey and predator populations nationally and regionally in Scotland. Whilst the focus of the review is Scottish trends, these are considered in the context of UK/European/global population status/change, as appropriate.

Species considered

The current review includes all bird species on the General Licence 01-03 (see <http://www.snh.gov.uk/protecting-scotlands-nature/species-licensing/bird-licensing/general/>) and those contributing to the farmland and upland elements of the Scottish Wild Breeding Bird Indicator (<http://www.snh.gov.uk/docs/B536405.pdf>), with the exception of sawbills and cormorants, which are being considered elsewhere). For predatory mammals, the reviewing includes all those species relevant to interactions with wild birds, including feral cats.

Mammal population information

Whilst information about the distribution, and in some cases abundance, exist for some UK mammals, data are very sparse for some species, and robust information on population trends is largely lacking (Harris *et al.* 1995; Battersby *et al.* 2005). In part this is due to the difficulties in observing mammals which tend to be at relatively low densities, and are often nocturnal and elusive; some may also require species-specific survey designs. Nevertheless, there are several single- and multi-species schemes that record mammals, as well as a number of national surveys; in 2003 The Tracking Mammal Partnership (TMP), a collaboration between 24 organisations, was set up to bring together all existing data together and provide a co-ordinated structure for future monitoring and surveillance (Battersby & Greenwood 2004; Battersby *et al.* 2005).

For the majority of mammals which are being monitored on an annual basis, the first report of the Tracking Mammal Partnership (2005) provides trends at a UK level for the period 1995-2005. An update to 2007 (2008 for some species) is also available (Tracking Mammal Partnership 2009). The Tracking Mammal Partnership (2005) report provides an outline of each of the schemes (see key below) and contributing organisations and we have not reproduced this information here. However, it is important to note that the length of time these schemes have been operating varies considerably, with the longest time-series available for the National Gamebag Census which collates data from shooting estates in England, Wales, Scotland and Northern Ireland (Aebischer *et al.* 2011).

As well as records on “quarry” species, the census also contains information on the numbers of predatory birds and mammals that are legal to kill. A key difference between this scheme and the others including in the TMP is that the number of animals recorded depends on both the abundance of the species and the effort invested in killing them (e.g. number of gamekeepers per site, number of traps set), which means that care is required in interpreting the resulting trends. However, an examination of these issues concluded that whilst variation in effort added noise to the trend data, the available evidence, including a comparison with other monitoring schemes, suggested that the underlying trends reflected species abundance (Whitlock et al. 2003).

Key to acronyms for mammal population information are: The National Gamebag Census (NGC); The Breeding Bird Survey – Mammals (BBS); the Waterways Breeding Bird Survey – Mammals (WBBS); Mammals on Roads (MOR); Winter Mammal Monitoring (WMM); Garden Bird Watch (GBW), Living With Mammals (LWM); English House Condition Survey (EHCS).

Main sources of information and standard analyses for birds

Bird Atlas 2007-11

The BTO/BirdWatch Ireland/SOC [Bird Atlas 2007-2011](#) project aimed to provide updated distribution maps for all species which occur in both the breeding season and winter in all of Britain and Ireland. Methods employed were similar in both seasons and were similar to those employed in the 1988-1991 breeding atlas (below) but different to those for the 1981/82-1983/84 winter atlas or the 1968-1972 breeding atlas. The basic units of distribution were the 10-km squares of the National Grids of Britain and Ireland and the intention was to provide both distribution maps and an estimate of relative abundance in each 10-km square in both season. Fieldwork spanned 4 winters and 4 breeding seasons, starting in November 2007. The aim was to survey the whole of Britain and Ireland (all 10-km squares with land) by the end of the project period, although in Ireland there was a system of priority squares (alternate 10-km squares, the “chequerboard”). There were two complementary fieldwork methods. *Timed Tetrad Visits* (TTVs) were used to produce an estimate of relative abundance in each 10-km square. Observers were requested to walk around a tetrad (2-km square) for 1 (or optionally 2) hours and count all the birds seen or heard. Counts from the first hour and second hour were kept separate. Observers were asked to aim to survey all the major habitat types present in the tetrad and count all individuals of all species (winter), or all the adults of all species (breeding season; excluding juveniles (birds of the year) from counts whenever possible to distinguish these). Any evidence of breeding was noted (even during the ‘winter’ surveys), and observers were asked to visit once early in the season (November/ December for winter and April/May for breeding season) and once late (January/February for winter and June/July for breeding season). Once the four visits to a tetrad had been carried out, then that tetrad was finished as far as TTVs for the national atlas were concerned and there was no need to survey it in a subsequent winter or breeding season. TTVs did not aim to produce a complete species list for the tetrad, but a sample of what could be found during a pair of visits in winter and/or summer. The aim was to survey at least 8 tetrads in every 10-km square in Britain and Ireland during both winter and summer. The second fieldwork type, *Roving Records*, aimed to ensure that as complete a species list as possible was obtained for each 10-km square in both the winter and the breeding season. All systematic or casual records of species could potentially be included and records of those species often missed during the systematic surveys were particularly valuable (e.g. nocturnal species such as

owls), as were records containing evidence of breeding. Some areas carrying out concurrent local atlas projects requested similar records for each tetrad. The list and number of species recorded in each 10-km square are as complete as possible. Squares visited for less time are likely to have fewer species recorded and the rarer and more elusive species (e.g. nocturnal) are most likely to be under-recorded in such circumstances. The maps as published are a true representation of the distribution of the species at a national level, but there will be some gaps in individual squares and this much be considered when interpreting results at finer (e.g. regional) resolution. The project covered the whole of Britain, Ireland, the Isle of Man and the Channel Islands. All 10-km squares with more than a very small amount of land could be visited. In areas with sufficient observers, a high proportion of the 2-km squares in each 10-km square were visited for a standard count time but in the less well-populated areas only the minimum eight was covered (and not all 10-km squares in Ireland). As the specified purpose was to compile as complete a list as possible at the 10-km square resolution, the species lists in tetrads were not complete but were only those recorded in the 2 (or 4) hours of timed visits in each season. Survey timings were: Winter Season: 1 November to 28/29 February in each of 2007/08 - 2010/11; Timed Tetrad Visits were divided into Early (November/December) and Late (January/February) periods; Breeding Season: 1 April to 31 July in each of 2008 - 2011; Timed Tetrad Visits were divided into Early (April/May) and Late (June/July) periods. Evidence of breeding was recorded at any time of year.

For Scotland, comparisons of breeding distributions between the three atlas periods, and of relative abundance change since the last 1988-91 breeding atlas, alongside Breeding Bird Survey trends from 1994 for a sub-set of species, now provide comprehensive evidence of trends since the late 1960s.

The publication arising from the 2007-11 Bird Atlas project (Balmer *et al.* 2013) provided comprehensive analysis of changes in distribution and abundance at the scale of Britain and Ireland. For the current project, these analyses were refined to provide estimates of change for the whole of Scotland and for Scottish regions (administrative areas and biogeographical Natural Heritage Zones or NHZs; Figure 3) for those species for which such analyses were appropriate.

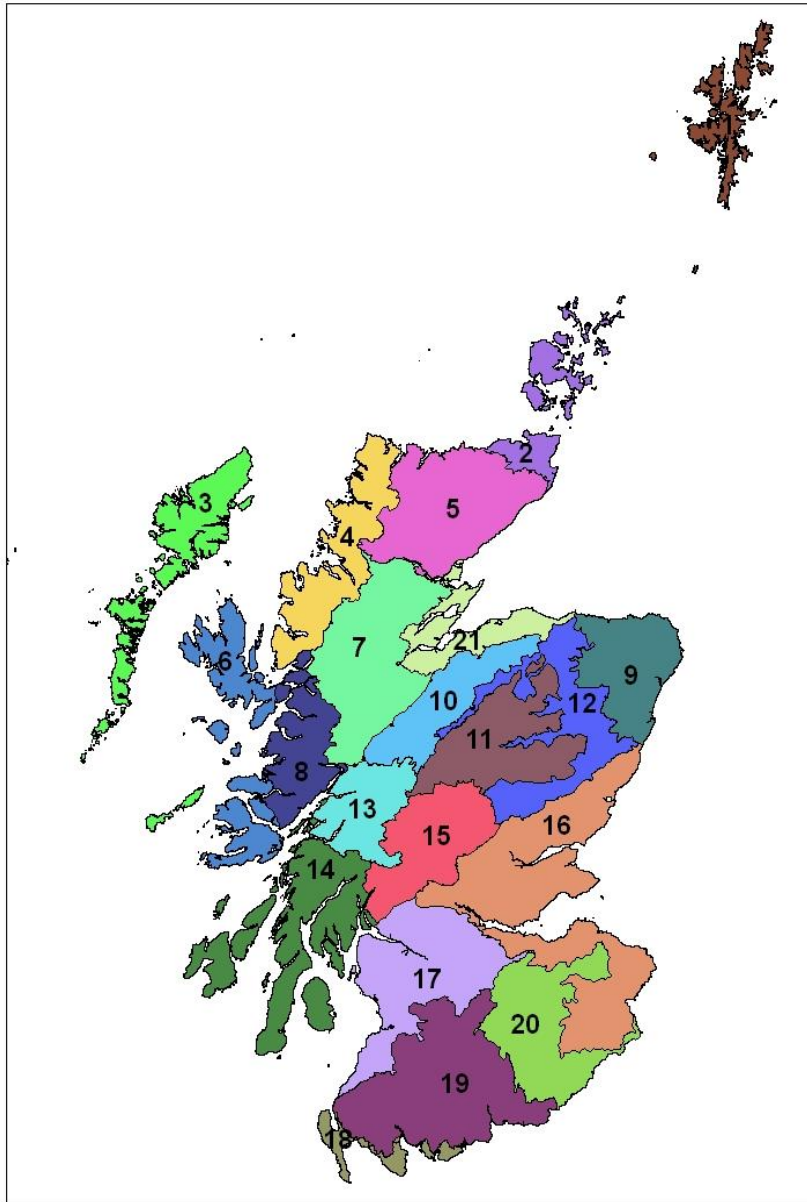


Figure 3. The Natural Heritage Zones (NHZs) of Scotland.

1= Shetland, 2 = North Caithness and Orkney, 3= Coll, Tiree and the Western Isles, 4 = North West Seaboard, 5 = The Peatlands of Caithness and Sutherland, 6 = Western Seaboard, 7 = Northern Highlands, 8 = Western Highlands, 9 = North East Coastal Plain, 10 = Central Highlands, 11 = Cairngorm Massif, 12 = North East Glens, 13 = East Lochaber, 14 = Argyll West and Islands, 15= Loch Lomond, the Trossachs and Breadalbane, 16 = Eastern Lowlands, 17 = West Central Belt, 18 = Wigtown machairs and Outer Solway Coast, 19 = Western Southern Uplands and Inner Solway, 20 = Border Hills and 21 = Moray Firth.

(Source: Reproduced by permission of Ordnance Survey on behalf of HMSO. © Crown copyright and database right 2013. All rights reserved. Ordnance Survey Licence number 100017908.)

Previous breeding bird atlases

Two previous atlases of the distribution of breeding birds covering the whole of Britain and Ireland have been completed: the first over five breeding seasons, 1968-72 (Sharrock 1976); and the second over four breeding seasons, 1988-91 (Gibbons *et al.* 1993). Both show the distribution of all breeding species based on 10-km squares. The first gives only categories of evidence for breeding within each 10-km square. The second repeats this approach but also introduces quantitative measures of 'relative abundance' based on timed counts within sample tetrads (2 x 2 km squares) within each 10-km square. Such counts of 'relative abundance' are not a measure of the absolute breeding population in each sample unit but rather, for most species, form an 'index' of the total population that is directly comparable between the sample units and through time if the same methods are repeated (as in the 2007-11 atlas above). Comparison of the results of the two previous atlas surveys permits an assessment of broad changes in distribution (though not abundance) during the 20-year interval between the periods covered but differences in effort and priorities during fieldwork between the two atlases do complicate direct comparison to some degree (Donald & Fuller 1998P, Vaisanen 1998P). In some cases information, regional bird trend information was also drawn from regional Scottish bird atlases, some of which collected data at higher spatial resolution.

Seabird censuses and Seabird Monitoring Programme (SMP)

National surveys of breeding seabirds, including Cormorants and Shags, have been undertaken in Britain and Ireland during 1969-70 (Operation Seafarer, Cramp *et al.* 1974), 1985-88 (Seabird Colony Register, Lloyd *et al.* 1991) and 1998-2002 (Seabird 2000, Mitchell *et al.* 2004). These have aimed to achieve comprehensive coverage of all coastal colonies using species-specific field methods. The most recent, 'Seabird 2000' (1998-2002) was the first to attempt comprehensive coverage of all colonies including those inland, although some inland colonies were included in earlier surveys. The [Seabird Monitoring Programme](#) (SMP; see <http://jncc.defra.gov.uk/page-1550>), organised by JNCC, publishes the results of annual monitoring from selected representative seabird colonies (e.g. Mavor *et al.* 2003REP), providing more continuous data to supplement and validate the trends apparent from the three national censuses.

Breeding Bird Survey (BBS) and the Common Bird Census (CBC)

These two multi-species surveys are designed to monitor the relative abundance of widespread species and provide trends through time in breeding bird populations. The BTO/JNCC/RSPB [Breeding Bird Survey](#) (BBS) assesses changes in the number of registrations for species encountered along fixed transect routes within randomly selected 1-km squares across the UK (e.g. [Harris *et al.* 2015](#)). Volunteers make two early-morning visits each year (the first in April or early May, and the second in late May or June) to their square to record the birds that are seen or heard while walking along a set transect route. This route ideally consists of two 1-km parallel straight lines 500m apart and 250m from the edge of the square. However, practical considerations mean that the actual route is usually a compromise between this and what is physically possible given the terrain and access considerations. The route is divided into ten 200m sections, and in each section birds are recorded in three distance bands, within 25m, 25-100m and more than 100m from the transect line. Birds flying over are recorded separately. Observers are also asked to record the main habitats on each section (normally on a separate visit before the first bird recording visit). The ideal is for each volunteer to survey the same square (or squares) each year. Full instructions and recording forms can be viewed

at: www.bto.org/volunteer-surveys/bbs/taking-part/download-forms-instructions. Starting in 1994, the BBS replaced the Common Birds Census (CBC, a more intensive territory mapping approach) as the principal monitoring programme for many widespread bird species in the UK. The CBC monitored widespread breeding bird species in farmland and woodland habitats only between 1962 and 2000 (Marchant *et al.* 1990, Crick *et al.* 2003) and was carried out on only 200- 300 sites each year, due to the more intensive survey methods employed. Trends from the two surveys have, however, been linked to enable production of a continuous set of trend data (at UK or England scale only) from the early 1960s to the present. Unfortunately CBC surveying was highly biased towards southern and eastern Britain in its coverage. Although some sites in Scotland contributed, these were generally too few to allow production of population trends for Scottish populations alone. BBS provides much improved coverage in Scotland (474 random 1-km squares covered in 2014; See [Harris *et al.* 2015](#) p.9), with 62 species being recorded on an average of 30 or more 1-km squares, the minimum sample taken as a working threshold for generating reliable trends in bird abundance ([Harris *et al.* 2015](#)).

Single species surveys

Specific comprehensive (UK- or Britain and Ireland-wide) surveys have been undertaken for a number of the species included in this review, often under the banner of the Statutory Conservation Agencies and RSPB Annual Breeding Bird Surveys (SCARABBS) programme. These are generally designed to provide rigorous estimates of breeding population size (and population change, where these have been repeated more than once), using methods and timings of observations selected to match the breeding biology of the focal species. Such surveys have been carried out for some of the birds of prey considered in detail in the current project (e.g. Golden Eagle, Hen Harrier, Merlin, Peregrine), generally involving either: (a) periodic complete coverage of all known breeding sites from previous surveys and ongoing monitoring work (preferably with some kind of appropriate sampling of areas outside of the previous range to check for range change or population re-distribution; e.g. Golden Eagle); (b) a mixture of complete coverage in some areas and random sampling in others (e.g. Peregrine, Hen Harrier); or (c) surveys based entirely on a sampling approach of appropriate design for the focal species. No such survey can ever provide 100% coverage but there are rigorous accepted scientific methods of dealing with coverage anomalies in these well-designed surveys, such that statistical confidence limits can be attached to population estimates and trends, showing the most likely range of possible outcomes.

Pre-1960 population information

The current review focused on population changes of wild birds and their main predators since 1960. This was because little rigorous population information from structured surveys exists prior to that time for the majority of species. However, to provide important past context, and to assist in explaining likely drivers of population change, we have also referred to information from before 1960 in many of the species accounts. For some species, particularly the birds of prey and those on which monograph books have been written, past populations have been researched in detail (e.g. Newton 1988 for Sparrowhawk; Village 1990 for Kestrel ; Ratcliffe 1993 for Peregrine; Ratcliffe 1997 for Raven; Watson 2010 for Golden Eagle). Such detailed studies have drawn on information from a wide range of historical sources, including individual studies by established field naturalists, records from shooting estates and existing reference works on historical distributions (e.g. Holloway 1996)

and populations in Scotland (e.g. Baxter & Rintoul 1953; Thom 1986; Forrester et al. 2007). Whilst the time available for the current review did not allow us to carry out a full systematic review of Scottish bird and mammal trend information, we consider that the overviews we present for trends prior to 1960 are adequate for providing context for more recent changes.

2.1.2 OTHER PROJECT-SPECIFIC ANALYSES

Derivation of Atlas abundance change statistics for Scotland and by land types

Two atlases of breeding birds include representative data at the 2-km square (tetrad level) as well as comprehensive coverage at hectad (10-km square) resolution (1988–91 and 2008–11; Gibbons *et al.* 1993, Balmer *et al.* 2013). Change in the proportion of surveyed tetrads within each hectad (range 8 – 25 tetrads per hectad, but less for some incomplete coastal hectads) in which surveyors encountered a species is a proxy for change in relative abundance of that species within that hectad during the 20 year interval between the two atlas periods (essentially 1990 – 2010).

Mean and 95% confidence intervals for changes in breeding abundance were calculated for each species using the changes in occupied tetrads within each hectad in each of the three land-type classifications. We restricted our analysis to 154 bird species that were found to occur in at least 25 hectads in Scotland during the breeding season ([Appendix S4](#)). Although data are proportions, all calculations assumed a normal distribution as their actual distribution did not differ from normality (Kolmogorov-Smirnov goodness of fit test $D = 0.06$, $P < 0.01$) and also for ease of interpretation. Species were described as having decreased if the mean change was negative and the confidence intervals did not overlap zero. Similarly, species were described as having increased if the mean change was positive and the confidence intervals did not overlap zero. The remainder had either shown no change or else there was insufficient power to detect change.

For the analyses according to land type, each 10-km square (hectad) of the Ordnance Survey's national grid was classed into one of three categories ('Upland', 'Mixed' and 'Lowland') by using habitat data from the Land Cover Map 2000 (LCM2000; Fuller *et al.* 2002). Firstly, an 'upland habitat' category was created by combining the categories for heath, mire and acid grassland. Each 1-km square was then defined as of 'upland character' if 30% or more of that square was classed among the 'upland habitat' categories by the LCM2000. Each hectad was then classed as: 'Upland' if 75% or more of the 1-km squares were of upland character ($n = 515$); 'Mixed' if between 25% and 75% of the 1-km squares were of upland character ($n = 208$); and 'Lowland' if 25% or less of the 1-km squares were of upland character ($n = 289$) (Figure 4). Statistically significant differences in abundance changes between land-types were assumed when there was no overlap between the confidence intervals around the mean change. We excluded species occupying less than 10 hectads in any given land type from this analysis.

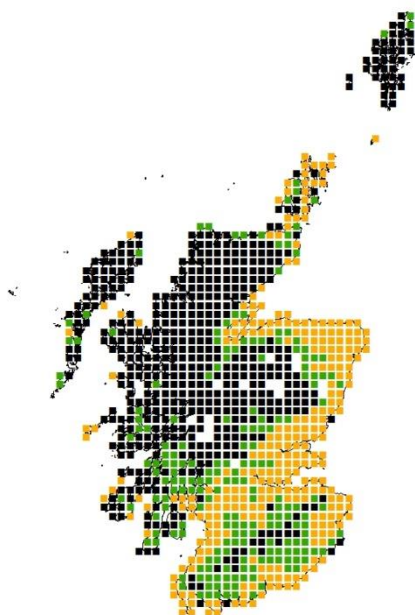


Figure 4. The distribution of 'Upland' (Black), 'Mixed' (Green) and 'Lowland' (Yellow) hectads in Scotland as defined using habitat data from LCM2000. Blank hectads are those for which there are insufficient Bird Atlas data at the tetrad level.

2.1.3 FORMAL LITERATURE-SEARCHING METHODS

The current project aimed to review:

- The drivers of change in predator (including mammalian) and wild bird prey populations, to include a full range of both environmental and direct human influences (e.g. afforestation, agriculture and other land-use change, climate change, legal and illegal predator control, recreational disturbance). For migratory bird species, influences outside as well as within Scotland and the rest of the UK are considered.
- The relationships between predators and wild bird prey populations (including predator intra-guild interactions and feral cats as they relate to wild bird prey), starting from the premise that predation is a natural ecological process and drawing out both positive and negative aspects of predation.
- Key interactions in relation to three focal groups: upland waders; lowland waders; and wild gamebirds and a selection of focal species (see below).
- Management experience, that is the evidence for the success, or otherwise, (likely outcomes) of a range of established (or recognised) management options for these key interactions.

The principles of a formal systematic review were adopted. The online literature database Web of Science (WoS) was searched for relevant literature using pre-defined search terms. These searches were divided into four main groups, each aimed at identifying literature relevant to a different aspect of the review: ecology of the six focal prey species, effects of predators on wild birds, other drivers of change affecting wild bird populations, and evidence for effectiveness of management techniques. Search terms were constructed to balance volume of literature returned with scope and comprehensiveness of the search. The search terms used for each of these types of search are explained below.

Focal species

Six separate searches (searches 1 to 6) were carried out, each requiring that topic words included either the common name or scientific name of one of the six focal species (Table 1). Only records including a European country or “Europe” in the topic were included, and the search was not date-restricted.

Table 1. Search terms for literature relating to focal species. All searches included all of the common terms in TITLE, ABSTRACT and KEYWORDS. Search settings covered all years in the database (1864 - 2015). Each search also contained one specific term, relating to a focal bird species, that was searched in TITLE, ABSTRACT and KEYWORDS.

Criterion	Common terms	
	(EUROPE or ESTONIA OR CROATIA OR GERMANY OR SLOVAKIA OR SPAIN OR IRELAND OR FRANCE OR GREECE OR ENGLAND OR LATVIA OR "UNITED KINGDOM" OR UKRAINE OR POLAND OR SLOVENIA OR "UK" OR BULGARIA OR ITALY OR NETHERLANDS OR WALES OR SWEDEN OR FINLAND OR ROMANIA OR SWITZERLAND OR ICELAND OR NORWAY OR DENMARK OR IRELAND OR BELGIUM OR CZECH* OR PORTUGAL OR SCOTLAND OR HUNGARY OR AUSTRIA OR BOSNIA OR YUGOSLAVIA OR ALBANIA OR MACEDONIA OR KOSOVO OR SERBIA OR MONTENEGRO OR LUXEMBOURG OR ANDORRA OR MONACO OR RUSSIA)	
AND		
Search	Specific term	Hits
1	"EURASIAN CURLEW" or "NUMENIUS ARQUATA"	685
2	"EURASIAN OYSTERCATCHER" or "HAEMATOPUS OSTRALEGUS"	1167
3	"EUROPEAN GOLDEN PLOVER" or "PLUVIALIS APRICARIA"	470
4	"NORTHERN LAPWING" or "COMMON LAPWING" or "VANELLUS VANELLUS"	1784
5	"BLACK GROUSE" or "TETRAO TETRIX"	1083
6	"GREY PARTRIDGE" or "PERDIX PERDIX"	908

Effects of predators

Nineteen searches were carried out, each requiring that results included both of the terms BIRD* and PREDAT* (to increase the chance that it would include information about the effects of predation on birds), one of the terms POPULATION* or PRODUCTIVITY or REPRODUC* or SURVIV* or ABUNDANCE* or DISTRIBUT* (to focus the search on literature dealing with effects on bird populations), and the common or scientific name of one of 19 avian predators of wild birds in Britain and Ireland (searches 7 to 24), or elements of common or scientific names of the main mammalian predators of wild birds (searches 25 to 33) (Table 2 for details). Only records including a European country or “Europe” in the topic were considered, and the search was restricted to the period since the writing of the previous review - 2005 to 2015.

Table 2. Search terms for literature relating to predator effects. All searches included all of the common terms in TITLE, ABSTRACT and KEYWORDS. In addition, searches were restricted to the period 2005 - 2015 inclusive. Each search also contained one specific term, relating to one or more predator species, that was searched in TITLE, ABSTRACT and KEYWORDS.

Criterion	Common term
AND	BIRD*
AND	PREDAT*
AND	(POPULATION* or PRODUCTIVITY or REPRODUC* or SURVIV* or ABUNDANCE* or DISTRIBUT*)
AND	(UK or "UNITED KINGDOM" or "BRIT*" or WALES or SCOTLAND or IRELAND or ENGLAND)

Search	Specific term	Hits
7	("Carrion Crow" or "Corvus corone")	83
8	("Hooded Crow" or "Corvus cornix")	46
9	("Northern Raven" or "Corvus corax")	30
10	("Golden Eagle" or "Aquila chrysaetos")	45
11	("Common Buzzard" or "Buteo buteo")	109
12	("Red Kite" or "Milvus milvus")	34
13	("Northern Goshawk" or "Accipiter gentilis")	111
14	("Sparrowhawk" or "Accipiter nisus")	119
15	("Peregrine" or "Falco peregrinus")	71
16	("Hen Harrier" or "Circus cyaneus")	55
17	("Tawny Owl" or "Strix aluco")	93
18	("Short-eared Owl" or "Asio flammeus")	19
19	("Arctic Skua" or "Stercorarius parasiticus")	7
20	("Great Skua" or "Stercorarius skua" or "Catharacta skua")	27
21	("Great Black-backed Gull" or "Larus marinus")	25
22	("Lesser Black-backed Gull" or "Larus fulvus")	18
23	("Herring Gull" or "Larus argentatus")	43
24	("Common Gull" or "Larus canus")	16
25	("Black-headed Gull" or "Chroicocephalus ridibundus" or "Larus ridibundus")	32
26	(Rat or Rattus)	126
27	(Cat or Felis)	100
28	("Red Fox" or "Vulpes vulpes")	183
29	(stoat OR weasel OR "pine marten" OR polecat OR ferret OR mink OR Mustela)	150
30	(otter OR "Lutra lutra")	33
31	(squirrel OR sciurus)	44
32	("European Hedgehog" or "Erinaceus europaeus")	17
33	("Badger" or "Meles meles")	23

Drivers of change

Eleven searches (searches 34 to 44) were carried out to identify drivers of change in wild bird populations, each requiring that results included the term BIRD* and excluded the terms POULTRY and CHICKEN (to minimise the inclusion of agricultural literature in the results). An additional search (search 45) was carried out to identify drivers of change in mammalian predators, substituting the term BIRD* with a composite term OR term comprising the elements of mammal names included in searches 25 to 33 (see Table 3 for details). In order to restrict the results to literature dealing with effects on populations, each search included a set of alternative demographic terms similar to that included in type 2 (Effects of predators) searches. However, in order to reduce the number of non-relevant records returned, the term POPULATION* was replaced with more specific terms relating to population change: "POPULATION CHANGE" or "POPULATION GROWTH" or "POPULATION DRIVER*" or "POPULATION INCREASE*" or "POPULATION DECREASE*". Each search also included a composite term intended to focus it on literature dealing with one of eleven categories population drivers: predation, environment, climate, land-use, habitat, food availability, disease, grazing, chemicals and non-native species (Table 3 for details). Only records including UK or "UNITED KINGDOM" or BRIT* or WALES or SCOTLAND or IRELAND or ENGLAND were considered, and the search was restricted to the period since the writing of the previous review - 2005 to 2015.

Table 3. Search terms for literature relating to drivers of wild bird population change. All searches included all of the common terms in TITLE, ABSTRACT and KEYWORDS. In addition, searches were restricted to the period 2005 - 2015 inclusive. Each search also contained one specific term, relating to one or more drivers of change, that was searched in TITLE, ABSTRACT and KEYWORDS.

Criterion		Common term
AND	BIRD*	
NOT	(POULTRY or CHICKEN)	
AND	("POPULATION CHANGE" or "POPULATION GROWTH" or "POPULATION DRIVER*" or "POPULATION INCREASE*" or "POPULATION DECREASE*" or REPRODUC* or SURVIV* or ABUNDANCE* or DISTRIBUT*)	
AND	(UK or "UNITED KINGDOM" or "BRIT*" or WALES or SCOTLAND or IRELAND or ENGLAND)	
Search	Specific term	Hits
34	PREDAT*	905
35	"environment* change"	55
36	"CLIMATE CHANGE"	297
37	("LAND USE" or ABANDON* or INTENSIFI* or AFFOR*)	396
38	"HABITAT CHANGE" or "HABITAT QUALITY" or "HABITAT IMPROVEMENT" or "HABITAT SUITABILITY"	141
39	("food availability" or "food supply" or "food source*" or forag* or diet*)	1057
40	DISEASE or PATHO* or parasit*	555
41	DISTURBANCE*	898
42	(DEER or LIVESTOCK or GRAZ* or SHEEP or CATTLE)	280
43	(HERBICID* or PESTICID*)	103
44	(INTRODUC* or NON-NATIVE or INVASIVE)	228
45	((Rat or Rattus) not (medic* or vet*)) or ((Cat or Felis) not (medic* or vet*)) or "Red Fox" or "Vulpes vulpes" or stoat OR weasel OR "pine marten" OR polecat OR ferret OR mink OR Mustela or otter OR "Lutra lutra" or squirrel OR sciurus or "European Hedgehog" or "Erinaceus europaeus" or "Badger" or "Meles meles"	568

Effectiveness of management

One search (search 46) was carried out for literature relating to management for wild gamebirds and waders, specifying one of three terms relating to management (MANAGEMENT or MITIGAT* or "PREDAT* CONTROL"), one of seven terms relating to gamebirds and waders (GAMEBIRD* or SHOREBIRD* or WADER* or "WADING BIRD*" or "GROUSE" or "PHEASANT*" or "PARTRIDGE*") one of four terms related to demographic targets of management (POPULATION* or PRODUCTIVITY or REPRODUC* or SURVIV* or CONSERV*). Only records including UK or "UNITED KINGDOM" or BRIT* or WALES or SCOTLAND or IRELAND or ENGLAND were considered, and the search was not date-restricted (Table 4).

Table 4. Search terms for literature relating to management of wild bird populations. This search (search 46) included all of the following terms in TITLE, ABSTRACT and KEYWORDS. Search settings covered all years in the database (1864 - 2015). This search returned 793 hits.

Criterion	Common term
AND	(MANAGEMENT or MITIGAT* or "PREDAT* CONTROL")
AND	(GAMEBIRD* or SHOREBIRD* or WADER* or "WADING BIRD*" or "GROUSE" or "PHEASANT*" or "PARTRIDGE*")
AND	(POPULATION* or PRODUCTIVITY or REPRODUC* or SURVIV* or CONSERV*)
AND	(UK or "UNITED KINGDOM" or "BRIT*" or WALES or SCOTLAND or IRELAND or ENGLAND)

The results of each search were saved as records in a separate collection in reference manager software Zotero. The records in each search included (where relevant) title, authors, keywords, source, date and abstract of each item returned by the search.

The scope of literature returned by the above searches was assessed by re-running all of these searches on time period up to 2005, and determining the proportion of the literature in the bibliography of the previous review (Park *et al.* 2005) that was also returned by our searches. Any literature covered in the previous review and not identified by our searches was used to check the efficacy of our search methodology, and to identify approaches to filling any gaps identified.

2.1.4 OTHER SOURCES OF INFORMATION FOR THE REVIEW

In addition to the systematic literature searches, and the review by Park *et al.* (2005), we drew on information from a number of other reviews of predation on wild birds, including Smith 2000, Valkama *et al.* (2005), Gibbons *et al.* (2007), Holt *et al.* (2008), Roos *et al.* (2012), Newton *et al.* (2013) and Madden *et al.* (2015). Primary studies referred to in these reviews, as well as in other literature that we encountered, were also included in the current review where they provided a clearer or more direct link to information or a line of reasoning relevant to this review.

Further literature sources were also brought to our attention by respondents to the social science questionnaire, other stakeholders, Project Steering Group members and members of the Project Review Panel. These ranged from single studies illustrating relevant issues, which stakeholders wished to ensure would be adequately addressed, to more comprehensive reviews and lists of literature covering broadly the same scope as this project. The main contributors of source material in this regard were the Game and Wildlife Conservancy Trust, Royal Society for the Protection of Birds, and Professor Ian Newton. All of this literature was included for consideration during the review, but was subjected to the same [reviewing criteria](#) as described for literature found during systematic searches. For the comparisons between results of the natural science review and stakeholder assessments of importance of population drivers and efficacy of management, we restricted consideration to the literature found during systematic searches, as well as the extensive sets of literature identified as relevant by GWCT and RSPB.

2.1.5 FORMAL SYSTEMATIC EVALUATION OF LITERATURE

The systematic searches of WoS described above generated an overall total of 14,747 records. However, many records were duplicated between searches. After elimination of duplicate records, the number of unique records was reduced to 10,078. These records were screened for potential relevance to the project, with records being excluded from further consideration on the basis of title, and then abstract. Studies dealing with populations of birds that are commonly released in the wild were considered in scope only when clear that they referred to individuals behaving, to some extent, as wild birds (e.g. nesting). Non-English literature without an English abstract was categorised separately, and not considered further (unless very specific knowledge gaps were identified), due to the extra time it would have taken to adequately translate and assess it.

Records deemed to be potentially relevant on the basis of both title and abstract were initially categorised on a three-point scale:

- Relevance level 1: deals with a process or relationship of direct relevance to the review;
- Relevance level 2: the topic falls within the remit of the review, but it is unclear whether the subject matter of the literature is directly relevant;
- Relevance level 3: unlikely to contain relevant information, but this possibility cannot be ruled out.

All literature classified as relevance level 1 (686[+relevance 1 mammal pre-2005]) was, where possible, examined in greater detail. Relevance level 2 records (2,363[+relevance 2 mammal pre-2005]) were examined only to check for information on topics which were poorly covered by relevance 1 literature, such that insufficient evidence had been reviewed to reach firm conclusions.

Literature was deemed to be relevant if it quantified a population-level effect or process and:

- at a European level, dealt with the predation of wild birds, or population regulation of any of the six focal species, or
- within Britain and Ireland, dealt with population regulation of terrestrial wild birds (or their mammalian predators) or the effectiveness of management techniques for wild birds.

All literature deemed to be within the scope of the review was coded according to the strength of population effect(s) suggested or demonstrated by the paper (either no effect demonstrated or a clear effect demonstrated in at least some situations), and the strength/quality of evidence on which this demonstration was based. Evidence for population level effects (including population size, survival and productivity) was coded as follows:

- A: experimental evidence or causal relationship demonstrated,
- B: correlative evidence
- C: anecdotal evidence or unsubstantiated claim.

Evidence for processes that could (but had not been shown to) affect population size, survival or productivity rates, was coded as follows:

- D: process fully quantified at prey population level (e.g. 50% of chicks in population predated)

E: process partially quantified (e.g. half of all prey items brought back to 10 Goshawk nests were Black Grouse)

F: process reported anecdotally, essentially unquantified (Red Fox is a frequent predator of Golden Plover nests). *[we can replace these examples with real ones we agree on later]*

The above codes for strength of evidence were applied to type of effect(s) described, predator species involved, and type(s) of bird impacted. Evidence was coded separately for each of the six focal species, and also to other groups of species *[to be determined later, according to those groups for which sufficient evidence is available (e.g. taxa, guilds or groupings by broad habitat association)]*.

All literature and other evidence suggested to us by stakeholders as providing relevance about effects of predation on wild birds was also included in the review process, being subjected to the same processes of screening for relevance and assessment for strength of effect and strength/quality of evidence described above.

2.2 Social science research methods

Even when science carried out to address the problems facing society is of the highest quality, it may be ignored or rejected by stakeholders if it is perceived as externally imposed and expert-oriented, focuses on issues or questions that are not seen as relevant, or fails to consider local conditions (Cooke and Kothari, 2001; Wynne, 1992). Many of these aspects can be captured by exploring the knowledge held and used by different groups, including knowledge held by specific groups of people about their local ecosystems (Scholz et al., 2004).

Integrating different types of knowledge in the decision-making process can improve the quality of decisions, through the inclusion of local actor values and interests (Huntington, 2000; Beierle and Konisky, 2001; Primmer and Kyllonen, 2006). In turn, decisions that are agreed upon collectively and acknowledge local concerns and knowledge are more likely to be socially and politically accepted (Harrison and Burgess, 2000; McCool et al., 2000), and can contribute to conflict resolution (Close & Hall, 2006; Young et al., 2010). There are, however, challenges in integrating different types of knowledge, including practical challenges linked to accessing local knowledge (see Sillitoe 2014 and Sillitoe and Filer, 2014), concerns around power-sharing between state and non-state actors (Taylor et al., 2012) and the perception that local knowledge may be “*insufficiently objective and insufficiently rigorous in terms of methods and documentation*” (Failing et al., 2007), thereby somehow lacking in scientific merit (Close & Hall, 2006).

The social science element of this research was conducted in three stages. Firstly, a quantitative web-based questionnaire was distributed to staff, volunteers and members of organisations considered to have an interest in the predation of wild birds in upland and lowland systems in Scotland. These stakeholder organisations were then invited to participate in workshops to discuss the findings of the questionnaire in more depth. Finally, stakeholders were brought together in three 'review seminars' to examine and help interpret similarities and differences between the natural science findings and the understanding of those relying on local knowledge. This mixed methodological approach aimed to address some known pitfalls regarding access to and veracity of

knowledge (Sillitoe 2014; Sillitoe & Filer 2014) and aimed to ensure that participants were able to communicate their own thoughts, experiences and knowledge, rather than conveying only their institutional perspective (see [section 2.3.2](#)).

2.2.1 SAMPLING STRATEGY

Invitations to participate in the questionnaire and workshop program were initially sent to 124 relevant organisations; 30 of which were members of Scotland's Moorland Forum ([Appendix 1](#)). Most organisations responded by promoting the project through their staff, volunteers and membership as well as their social media networks. Subsequently, researchers asked members of Scotland's Moorland Forum and initial questionnaire respondents to identify others who might participate in the questionnaire and workshop programme. This "snowball sampling" strategy aimed to overcome problems associated with sampling concealed populations and took advantage of the social networks of identified respondents to provide the researcher with an escalating set of potential contacts (Atkinson & Flint 2004). Access to the online questionnaire was also promoted on a blog (<http://understandingpredation.blogspot.co.uk/>) so that members of the broader community could participate in the research.

A limitation of this sampling method was that while research participants were initially selected by the researcher from a sampling frame (i.e. membership of the Moorland Forum) we could not, and indeed did not aim to, ensure proportional representativeness among organisations with different sized memberships or depth of experience in the subject matter. However, our aim here was to capture the range of views of representatives of the Moorland Forum and related organisations and individuals with an interest in and knowledge about the subject matter.

Individuals and representatives of organisations who submitted an online questionnaire were invited to participate in a workshop. Those who joined a workshop tended to be members of organisations that were most committed to the research objectives and who had the capacity to internally recruit representatives who were available at the appropriate time and location. Invitations to join the review seminars were sent to all 124 organisations identified above and to all questionnaire respondents. There were some stakeholder groups that were missing from the workshops and seminars, for example the National Farmer's Union Scotland (NFUS). This group was contacted and asked to attend a workshop, but they were unable to find a suitable date for a group of their members to participate. They were, however, encouraged to take part in the questionnaire, and a number of farmers attended the seminars. Participation at seminars was managed to ensure a broad spread of stakeholder perspectives was represented at each discussion. No barriers other than logistics were mentioned by the organisations that could not attend workshops and seminars.

2.2.2 QUESTIONNAIRE DESIGN

Posts and comments on the blog were initially used to help understand the issues and perspectives of stakeholders and these informed the development of the questionnaire. A structured, web-based questionnaire was designed to link with the natural science review using Qualtrics Survey Software

(www.qualtrics.com) ([Appendix 2](#)). The questionnaire focused on the following six topics ([Appendix 3](#)):

- i) Organisational affiliation and socio-demographic information;
- ii) Interest and experience of predation of ground-nesting wild birds in the uplands and lowlands of Scotland;
- iii) Preferred forms of knowledge
- iv) Perceptions of population abundance changes in predator and prey species;
- v) Drivers of change in prey and predators;
- vi) Conservation and management of predator-prey interactions.

Results from the questionnaire were then used to inform the structure and content of the subsequent workshops ([Section 2.2.3](#)). Many questionnaire respondents took significantly longer to complete the questionnaire than we estimated and provided very detailed comments throughout the questionnaire, suggesting they gave considered opinions and if asked the questions again would give very similar answers. To test the reliability of answers, participants were asked the questions again in the workshops where we presented questionnaire data provided by workshop participants. We found the answers to be consistent across the questionnaire and workshop discussions.

2.2.3 WORKSHOP PROGRAMME

In total, nine workshops were conducted with 62 participants representing 15 organisations between June and July 2015 ([Appendix 4](#)). A confidentiality agreement was read out at the beginning of each workshop and participants were asked for permission for the workshop to be audio recorded. The audio recordings were transcribed in full and these transcriptions formed the basis of the workshop analyses conducted for this report. Workshop reports were all approved by participants. Workshop discussions lasted approximately two hours and focused on the following broad topics to explore reasons for potential divergence of views between stakeholders and with findings from the natural science review: use of local and/or scientific knowledge; knowledge and understanding of changes in focal wild bird populations and the reasons for these changes; and understanding of and preference for different conservation-management goals for focal predator and prey species ([Appendix 5](#)).

2.2.4 SEMINAR PROGRAMME

Three, one-day seminars were held with research participants and other interested parties in Perth, Inverness and Edinburgh (October/November 2015) to enable those holding a range of perspectives to jointly discuss the preliminary findings. These involved a short presentation of initial project findings followed by discussion sessions to explore key results, discuss areas of agreement and disagreement between questionnaire and natural science review findings and develop shared ideas for future collaborative work. Questions for discussion sessions were adapted slightly for clarity between seminars based on participant feedback ([Appendix 6](#)).

2.3 Analyses

2.3.1 QUALITATIVE ANALYSIS - CODING

The qualitative data were analysed using the software program NVivo (v.10, QSR International Pty Ltd, Doncaster, Victoria, Australia). Transcriptions of open ended questions from the questionnaire and workshop discussions were imported into NVivo then manually coded. This sorted the information according to topics, themes and issues important to the study (Stake 2010). For example, workshop participants' comments relating to specific topics (e.g. land-use change) were sorted according to the issues they represented (e.g. increased use of herbicides having a major effect on the invertebrate food chain for Grey Partridge). The occurrence of different attitudes amongst our sample was quantified to identify which were most dominant among stakeholders, either by counting the number of individuals or by calculating the proportion of respondents within a knowledge group who made a statement.

2.3.2 CLASSIFYING STAKEHOLDER GROUPS

An iterative approach was used to classify stakeholder groups, based on a) existing theory on knowledge systems and b) the analysis of the questionnaire results, in particular the responses provided by respondents to questions 25 and 26.

Knowledge relates to our understanding of the world around us, and how we interpret our experiences and thoughts (Arce & Long 1992). Authors classify knowledge in different ways. Some make the distinction between local and scientific knowledge, between formal and informal or insider and outsider knowledge (Blaikie et al. 1997). Others, such as Aslin and Brown (2004) describe four knowledge systems to represent the diversity of knowledge, experience and expectations of different stakeholder groups. These include 'local knowledge' defined as "the body of knowledge held by a specific group of people about their local ecosystems" (Scholz et al. 2004: 336) - such knowledge can be site-specific and can be used to corroborate or fill gaps in scientific data; 'specialized knowledge', described as knowledge from experts, such as ecologists, sociologists and framed or constructed depending on the backgrounds of different groups; 'strategic knowledge', i.e. knowledge aimed at strengthening tactical positioning of groups or individuals; and 'integrative knowledge', a "mutual acceptance of overarching framework, direction or purpose, derived from a shared interpretation of the issues" (Aslin and Brown 2004).

These knowledge systems may not currently have equal weight in decision-making processes due to a range of professional and structural barriers often leading to a preference for 'appropriate' specialized knowledge experts, thereby concealing some values and accentuating others (Jepson & Canney 2003). However, it is important to consider the dynamic and often biased nature of knowledge through "*complex and ongoing processes involving selection, rejection, creation, development and transformation of information*" (Blaikie et al. 1997, p218), and the growing realization that social factors are a determinant of conservation success, thereby strengthening the argument for the need to include more and different types of knowledge systems.

With this in mind, and based on the analysis of the questionnaire responses, we classified questionnaire respondents into two groups, according to *the forms of information they identified as most important when learning about predation of ground-nesting wild birds*. Those who identified 'personal field observations or field management experience' (40%) as the most important form of knowledge were classified in the 'Local Knowledge' group – equivalent to the 'local knowledge' category as defined by Scholz et al. (2004) and Aslin & Brown (2004). Those relying primarily on 'academic/scientific peer-reviewed articles' (27%) were classified in the 'Scientific Knowledge Group' – equivalent to the 'specialized knowledge' group as classified by Aslin and Brown (2004).

Most other respondents to the questionnaire (20%) relied primarily on 'knowledge passed on through peers' – be they local peers or members of the same professional or recreational group. While this group can be classified as local knowledge based on the definition used earlier in this section, we carried out a further analysis based on the type of knowledge they actually used, rather than the type of knowledge they thought was most important. Those who used local knowledge 'always', or 'most of the time' and relied on scientific knowledge 'sometimes', 'rarely' or 'never', were included in the Local Knowledge group (52 respondents). If they said the opposite they were included in the Scientific Knowledge group (1 respondent). The remaining 26 respondents to the questionnaire stated that they used local and scientific knowledge equally and these were excluded from the analyses of the questionnaire results, along with the 11% of respondents who identified 'information prepared for licence applications', 'own scientific study', 'photographic evidence', 'popular press', or 'published or unpublished non-peer-reviewed literature' as most important form of information because the group was deemed too small to provide significant results ([Appendix 7](#)).

The categories of tactical and integrative knowledge were not implicitly mentioned in the questionnaire results. The mixed method approach used in this study, however, aimed to minimize strategic knowledge by allowing individuals to communicate their own personal perspectives. We acknowledge, however, the layers of constructs (from the individual to the institutional) that might inform participant responses.

This process resulted in a Local Knowledge group of 211 respondents (53%) and a Scientific Knowledge group of 110 respondents (27%). It is important to re-emphasize that the sampling strategy used was not meant to gather a broadly representative sample, but rather the aim was to capture the range of views of Moorland Forum and related organisations and individuals with an interest in and knowledge about the subject matter. There was overlap in knowledge use between the two groups. Many who stated that local knowledge was most important also habitually used scientific knowledge, and vice versa. In addition, a variety of organisations was represented within the Local and Scientific Knowledge groups, and many participants associated with than one organisation ([Appendix 8](#)). To summarize, these categories (local and scientific knowledge) indicate the preference for different groups of people over the forms of information they identified as most important when learning about predation of ground-nesting wild birds. As such, while the categorization is useful to explore associations between these groupings and understanding ways of thinking for the purposes of this project, we do not use them with the aim of categorizing or labelling sets of people.

Organisations that took part in workshops were also classified according to participants' choice of local or scientific knowledge as most important when learning about predation of ground-nesting

wild birds in general. Where participants did not exclusively choose local or scientific knowledge, they were classified according to the majority preference – again we acknowledge the overlap between the categories, and use these only to explore associations between these groupings and understanding ways of thinking for the purposes of this project. This resulted in six local knowledge and three scientific knowledge workshop groups.

Workshop participants spontaneously discussed diverse relevant topics to varying degrees. Some of the most relevant discussions for this report are included to indicate that some knowledge about these topics exists and is important to the research participants, and to reflect to some extent how this knowledge may be distributed throughout the stakeholder community. However, due to the spontaneous rather than prompted nature of many of these discussions this information cannot be said to reflect the entirety of knowledge held about any given topic. In some cases, themes are illustrated by direct quotations with the participant's knowledge category used to label their words, for example 'LK#1', 'LK#2', 'LK#3', 'LK#4', 'LK#5' and 'LK#6' represent the six local knowledge workshop groups while 'SK#1', 'SK#2' and 'SK#3' represent the three scientific knowledge workshop groups.

2.3.3 COMPARISON ON KNOWLEDGE

Throughout the results we compare the main findings arising from the Local Knowledge and Scientific Knowledge groups to highlight areas of agreement and disagreement. We also compare the findings from each of these groups with the information from the natural science review to understand how stakeholder knowledge compares with relevant published scientific knowledge.

2.3.4 UNCOVERING COMMONALITIES AND DIFFERENCES BETWEEN STAKEHOLDER KNOWLEDGE AND NATURAL SCIENCE REVIEWING

The questionnaire responses regarding focal predator and prey bird species trends were compared with BTO Bird Atlas data and differences were explored in workshops. As described in Section 4, relative abundance can be estimated as the proportion of tetrads (2km by 2km squares) occupied within a larger square (typically 10km by 10km or 20km by 20km). This measure of proportional occupancy scales log-linearly with abundance, except for very common and rarely detected species. For the focal prey and predator bird species considered here, it is likely that proportional occupancy is a good proxy for relative abundance. So, for each of the areas for which population changes were assessed by questionnaire respondents, change in the relative abundance of each species between the two Atlas periods was estimated as the proportional change in occupancy of tetrads.

We transformed both measures of change to make them comparable with one another. Respondent assessments remained on a five-point scale, but were transformed so that the score reflected the magnitude and direction of the assessment: -2: large decline; -1: small decline; 0: stable; 1: small increase; 2: large increase. The change in proportional occupancy was converted to the same scale as follows: -2: less than -0.2; -1: between 0.2 and -0.05; 0: between -0.05 and 0.05; 1: between 0.05 and 0.2; 2: greater than 0.2. A change in proportional occupancy of 0.2, over the range of abundances typically exhibited by the focal species, is approximately equivalent to a doubling (or halving, if negative) of abundance.

When comparing the importance of different factors driving change in populations of the six prey species as recognised through stakeholder responses and the scientific literature, we gave each factor a rank score. For the stakeholder groups ranks were based on the percentage of respondents that perceived each driver to have a 'medium to high impact on the prey population'. For the scientific reviewing, each driver was scored according to the evidence base that supported it, taking into account the number of relevant studies and consistency of their findings, the design and scale of the available studies, where studies were carried out (i.e. relevance to the Scottish context) and the strength of any driver effect found. The highest rank was 10, reflecting the most important driver for each species. It should also be noted that the scientific literature suggests much evidence for different drivers working together to influence population change ('interaction of effects') but comparable information was not collected in the questionnaire.

2.3.5 STATISTICAL ANALYSES

Statistical analyses were conducted in Minitab v17 and in R. We used non-parametric statistics to compare the species trends over 25 years as estimated by stakeholders and by the BTO bird Atlas data. We first used 2-sample Wilcoxon (Mann-Whitney) tests to explore differences between 1) Local and Scientific Knowledge respondents, 2) Atlas and Local Knowledge respondents and 3) Atlas and Scientific Knowledge respondents, for each species. Next we used Ordered Logistic Regression models to derive pseudo-r-squared values, and illustrate the relative contribution of species, source (Atlas or stakeholder) and Local or Scientific Knowledge.

We used χ^2 tests of association to compare the frequencies of respondents in different knowledge groups over their understanding of the importance of different factors in driving changes in abundance, and the effectiveness of different forms of management. We used Spearman Rank correlation to compare the ranked importance of different factors in driving changes in abundance, as understood by stakeholders versus the evidence from the literature.

2.3.6 QUESTIONNAIRE PARTICIPANTS – CHARACTERISTICS OF THE SAMPLE

The questionnaire ran between 31st May 2015 and 31st July 2015. In total, 1,382 questionnaires were initiated, 437 were submitted (i.e. the respondent progressed to the end of the questionnaire and deliberately clicked a button to 'submit' their responses). This is comparable with other quantitative studies of a similar length (Galesic & Bosnjak 2009). Of these, 400 were considered usable for analytical purposes because they included responses to more than half of the questions.

The majority of questionnaire respondents were male (89%), 9% were female and 2% preferred not to state their gender ([Appendix 9](#)). Most respondents (73%) were aged 45 years or over. The majority (61%) of people stated that they had held a personal or professional interest in the predation of ground-nesting wild birds in the uplands and lowlands of Scotland for over 20 years. Respondents' current or previous organisational associations (e.g. as an employee, volunteer or member) mostly involved conservation groups (74%), or groups associated with hunting, shooting and fishing (69%). Specific affiliations were with approximately 70 different organisations or professions, and many respondents held several affiliations ([Appendix 10](#)). Questionnaire

respondents were located throughout Scotland, but with greater representation from east Scotland and, in particular, eastern upland areas (Figure 5).

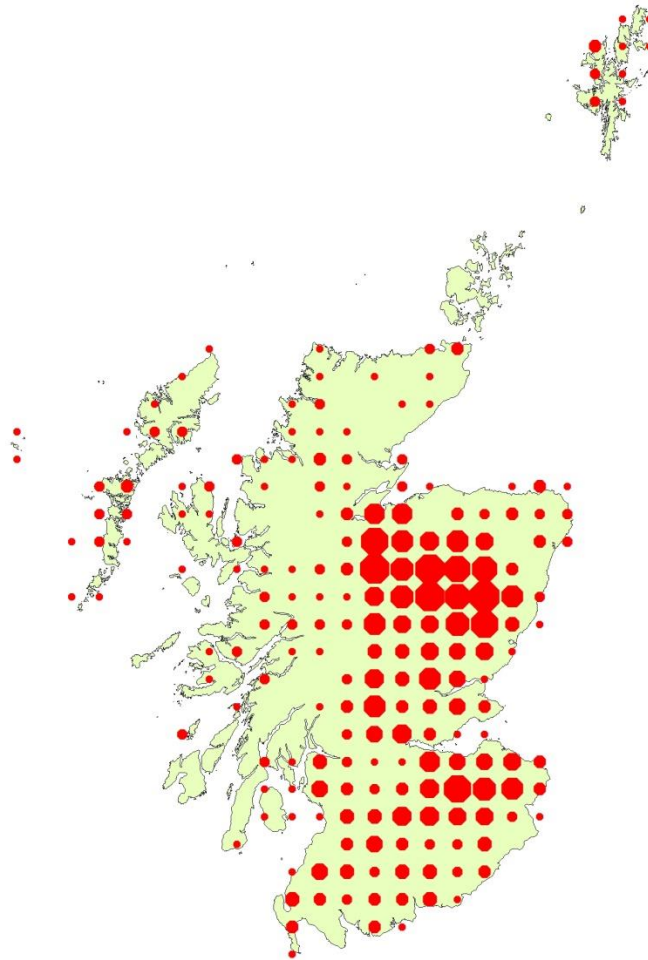


Figure 5. Distribution of 20km squares on which the questionnaire respondents based their assessments of population change (n=400). Size of circle represents the number of respondents who made assessments about each square, with the smallest circle representing 1 respondent, and the largest circle 16 respondents.

3. HOW DO STAKEHOLDERS GAIN AND USE KNOWLEDGE?

3.1 Ways in which stakeholders gain information

Participants in the social science strand of our study gave various reasons for relying on the different forms of knowledge. Both Local and Scientific Knowledge respondents trusted their preferred form of learning and knowledge and both relied on peers but for different reasons (Table 5).

Local Knowledge respondents valued the experience of witnessing first-hand the impact of changes in environmental conditions, including predation and habitat quality “...because you have witnessed events with your own eyes in a place you are very familiar with over a long time.” They regarded the years, decades or lifetimes of experience as providing them with an unparalleled breadth and depth of understanding of long-term ecological variations and trends. To many of these respondents the ‘man on the ground’ trusts his observations and considers them the most reliable, unbiased and appropriate source of information to carry out their professional role in their local area.

Those using local knowledge also explained that their peers often have significant ecological knowledge and experience which is relevant to their own situation and which can help them learn more about the impacts of predators and habitat loss for example on ground-nesting wild birds, especially where other sources of information (e.g. scientific studies) are lacking. These participants said they tend to rely on advice from a range of practitioners (e.g. land managers, farmers and conservationists) who have gathered local knowledge through long-term direct observation since these people are thought to have the most valuable and practical insights into relevant issues which could be adapted and applied elsewhere. Sharing ideas and problem solving were also important reasons for learning from peers, especially where knowledge is not formally recorded. Education was said to be vital, for example, day to day training, short courses and workshops were named as important ways for some respondents to benefit from the knowledge of their peers particularly regarding evidence-based decision-making and the implementation of best practice management strategies.

Among those relying on local knowledge there was a mistrust of how scientific evidence was reported because of perceived biases relating to who funds or peer-reviews the research, biases in the objectives and framing of studies, problems relating to geographic scale and timeframe, problems of generalisation from one location or species to another, and the potential for misinterpreting results due to the short-term ‘snap-shot’ of data gathered “It’s too easy to be led by....facts that were only the case at the time of the study.”

Those relying on scientific knowledge described the issue of predator-prey relations as an emotive, political or controversial subject. Such subjects require decision-making to be based on unbiased, independent, academically robust studies, preferably conducted by scientific organisations with significant relevant experience. Several valued the ability to conduct documented, repeatable experiments based on facts and sound observation and to apply data analyses which can help to reduce biases to a minimum and measure the significance of findings. Critical evaluation of scientific studies, particularly through peer-review was said by some to be paramount to the success of

scientific research because it allows evidence gathered to be tested to a high standard, scrutinised and challenged by well-qualified experts before publication. Respondents highlighted the fact that decision-makers, especially politicians, value scientific knowledge more highly than local knowledge, so scientific studies could potentially be used to positively influence the development of more appropriate legislation and management approaches regarding predator-prey interactions. A small number of respondents criticised what they saw as a historical reliance on circumstantial evidence which they suggested could polarise views and cause scepticism about the issues *“I respect and value people’s field experience greatly, but it is very easy to reach conclusions and be very firmly of a fixed point of view on things based on personal experience but still be wrong.”* This was related to a mistrust of non-scientific sources, such as news media and non-peer-reviewed literature written by non-government organisations which they said was sometimes politically motivated or could be influenced by the interests of some members.

Seminar participants considered that both local and scientific knowledge was needed. They considered that integration could build on the strengths of the different types of knowledge and address their weaknesses. In terms of processes required to combine the two types of knowledge in the future, participants noted the need to build trust, through better communication and the early involvement of local and scientific knowledge. Mechanisms were suggested in terms of how such integration could be achieved including increasing opportunities for networking and a steering group with impartial groups and good leadership to bring together collated views to government moving to action on areas where scientific and local knowledge holders agree and co-operating in further research or other activities in an attempt to reach consensus.

Table 5. Questionnaire respondents' reasons for choice of most important information when learning about predation of ground-nesting wild birds in general. Blank cells indicate blank cells indicate no comments made within in a knowledge group. Source: questionnaire respondents, n=321.

Reasons given for		Type of knowledge preferred	
		Local knowledge (211)	Scientific knowledge (110)
Trustworthiness	First-hand experience is vital for learning and understanding	(29%)	
	Develop intimate understanding of ecological variations and trends through daily contact with nature	(17%)	
	Predation is an emotive subject which requires objective data		(17%)
	Objective/factual evidence gathered		(14%)
	Evidence-based decision-making is important	(2%)	
	Reliability	(8%)	(8%)
	Lack of bias	(5%)	(17%)
	GWCT studies are important for conserving game and other wildlife		(4%)
	Trust in scientific methodology		(16%)

	Privileged form of knowledge		(5%)
Untrustworthiness	Mistrust of media		(2%)
	Mistrust of scientific evidence	(12%)	
	Mistrust of non-scientific or non-peer-reviewed data		(6%)
	Studies can be open to bias		(4%)
Professional interest	My scientific background		(3%)
Reliance on peers	Depth of ecological knowledge and experience gained over many years working on the land	(25%)	
	Peer review process / critical evaluation ensures rigour of data		(27%)
	Peers have relevant experience and knowledge	(6%)	
	Peers are important source of local ecological knowledge	(5%)	(1%)
	Share knowledge, ideas, thoughts or problems	(5%)	
Availability and accessibility of data	Lack of relevant scientific evidence	(1%)	
	Availability of good scientific studies		(1%)

	Information is formally recorded so can be studied by others		(1%)
Connection between local and scientific knowledge	Personal observations and scientific studies complement each other	(5%)	(4%)

3.2 Use of knowledge to make assessments about drivers of population change

Although participants from both knowledge workshop groups relied on diverse information sources to varying degrees to make assessments about drivers of population change, participants in the local knowledge group were more homogeneous in their use of information than the scientific knowledge group. Most participants prioritised ‘personal field observations, own scientific study or field management experience’ and ‘knowledge passed on through peers’ but many also referred to ‘academic/scientific peer-reviewed articles’, ‘published or unpublished non-peer-reviewed literature’ and ‘popular press’. There were said to be many studies demonstrating the importance of predation *“Science is important to back up understanding of managers and others relying on personal experience”* (LK#1). Participants from two scientific groups prioritised ‘academic/scientific peer-reviewed articles’ over other sources and one group also prioritised ‘published or unpublished non-peer-reviewed literature’, explaining that *“Science influences our thinking”* (SK#2). To a lesser extent, these participants also variously relied on ‘personal field observations, own scientific study or field management experience’ and ‘knowledge passed on through peers’.

When making assessments about the relative importance of different predator species impacting on the focal prey species, workshop participants relied on published material to a greater degree, especially non-peer-reviewed literature. This perhaps reflects a more widespread interest in studies on predators than on other kinds of environmental drivers or lack of available peer-reviewed research studying species of interest at appropriate geographic scales or locations.

An important point made by all workshop groups was the difficulty in extrapolating scientific evidence and local observations from one geographic scale or location to another. This was partly attributed to the dynamic nature of *“forever changing”* environmental systems, creating unique conditions for many land managers who cannot find scientific studies relevant to their particular circumstances *“I have to depend on my personal field observation... I need more regional research... on almost river catchment level... what happens on my ground is totally different... from friends and farmers and keepers nearby”* (LK#6).

4. POPULATION TRENDS OF WILD BIRDS AND THEIR PREDATORS IN SCOTLAND

4.1 Review of population trends for mammal predators of wild birds

In this chapter we aim to provide concise and accessible information on recent population changes of the regular avian and mammalian predators of wild birds in Scotland, and of their wild bird prey. For the predators, we provide an account for each species, and enhanced information for the five species that were included explicitly in the stakeholder engagement part of the project: common buzzard, raven, carrion and hooded crow and red fox. For our consideration of wild bird prey species, ground-nesting waders and gamebirds were our focus, with six species identified by stakeholders at project inception to exemplify the issues and discuss in more detail: lapwing; oystercatcher; curlew; golden plover; black grouse; and grey partridge. Here we provide enhanced accounts for those species to exemplify and explain the types of population information available for Scotland. We then provide a synthesis of recent population trends for other sub-sets of breeding terrestrial wild birds, involving groupings by taxonomy and land type where appropriate. While our focus is trends within Scotland, these are placed in the context of UK, EU and global trends and conservation status. We have aimed to provide comprehensive change information for Scotland within the main text and appendices, particularly where this derives from new analyses specific to this project and it is not easily accessible elsewhere. For other trend information to which we refer, we have provided links to primary web-based sources wherever possible.

EUROPEAN HEDGEHOG

Erinaceus europaeus

Information on population trends and status come from the following surveys: NGC, BBS, MOR, WBBS, GBW, LWM. There is some divergence on the direction of Hedgehog population trends between the different schemes surveying this species; whilst BBS indicates an upward trend in numbers, the NGC and WBBS both suggest a decline in abundance, at least in some areas. The 2009 update from the Tracking Mammal Partnership reports that whilst the decline at the UK level was not statistically significant, a significant decline in Wales between 1997 and 2008 was detected. Taken together with data from the NGC going back to 1960, there appears to be a long-term decline that started in the 1980s, with an estimated change of -52% (95% confidence intervals -9 to -74%) between 1960 and 2009 (Aebischer et al. 2011). Country-level trends are also available for Hedgehogs; the decline in England is estimated as -53% (2 to -78%) although as the confidence intervals span zero this is not statistically significant. In Wales the decline is -84 (-78 to -90%), and in Scotland a significant decline was noted between 1984 and 2009 (-40%; -4 to -59%). There were insufficient data to calculate trends for Northern Ireland.



Numerous studies have shown that food availability and predation from Badgers play key roles in determining the abundance, distribution and behaviour of European Hedgehogs (e.g. Doncaster 1992; Hof & Bright 2010; Trewby et al. 2014), with amenity grasslands in suburban areas though to represent spatial refugia from Badgers (Young et al. 2006). Hedgehog densities more than doubled on amenity grassland in areas where Badgers were culled as part of the Randomised Badger Culling Trial, providing strong evidence of mesopredator release, where reductions in the abundance of apex predators result in increases in smaller predators due to reduced intraguild predation, competition or changes in behaviour (Trewby et al. 2014). Radiotracking studies have indicated the importance of edge habitats, such as field margin and hedgerows for Hedgehog foraging and movement; therefore the intensification of agriculture which resulted in larger fields and reduced hedgerow density is likely to have reduced the carrying capacity of agricultural landscapes for Hedgehogs (Hof & Bright 2010). Studies from the UK and the Netherlands show that mortality on roads peaks in July and August and is biased towards the more widely ranging male adults (Reeve & Huijser 1999). However, in addition to mortality roads also act as agents of habitat fragmentation and barriers to Hedgehogs, Rondinini & Docaster (2002) showed a strong tendency of Hedgehogs to avoid crossing roads, with avoidance increasing in proportion to road width. The most likely drivers of declines in Hedgehog populations in the UK are therefore a combination of reductions in habitat quality caused by agricultural intensification and urbanisation, accompanied with increased mortality from traffic and higher density Badger populations.

RED SQUIRREL

Sciurus vulgaris

The Red Squirrel, once widespread throughout the UK is now found largely in Scotland and Northern Ireland with only a few isolated populations remaining in England and Wales. No trends were available from the TMP but since 2012 *Red Squirrels Northern England* has been conducting large scale systematic survey at 300 sites within the recently known range of Red Squirrels. Site occupancy of Red Squirrels during the four years the survey has been operating has remained relatively stable at 49% occupancy in spring (43.7% in 2015 – 53.6 in 2014). Two large-scale surveys in Northern Ireland in 1995-6 and 2002 indicated a net loss of Red Squirrels from four sites (out of a total of 80 surveyed; O'Neill & Montgomery 2003). An analysis of volunteer-collected distribution records of between 1991 and 2010 showed a consistent pattern of Red Squirrels being replaced by Greys (Gurnell et al. 2014). However, the rate of decline in Red Squirrel occupancy is variable across its range and in southern Scotland and across parts of the central lowlands occupancy appears to have increased 2007-2010. Nevertheless, based on current trends regional extinctions of Red Squirrel are estimated as 2020s in northern England to 2104 in North East Scotland (Gurnell et al. 2014).



Historic large-scale deforestation resulted in regional extinctions of Red Squirrels in many parts of Scotland by the 18th Century (Holmes 2015). Subsequent reintroductions from England and possibly the continent were successful but were followed by persecution from foresters and landowners for the damage the squirrels caused to trees and as a predator of birds' nests (Holmes 2015). The main current threat to Red Squirrel populations is from introduced Grey Squirrels which carry a pathogen

deadly to Red Squirrels (the squirrelpox virus, SQPV; Tompkins et al. 2003) and through interspecific competition (e.g. Wauters et al. 2000; Gurnell et al. 2004).

Differences in the physiology of the two species mean that Grey Squirrels are better able to exploit large seeds from deciduous trees giving them a competitive advantage in deciduous and mixed woodlands (Kenward & Holm 1989) and leading to reduced breeding success of Red Squirrels in the presence of Greys (Gurnell et al. 2004). However, of arguably more importance than competition are the severe impacts of SQPV (e.g. Tompkins et al. 2003; Rushton et al. 2006). The disease caused by this pathogen has no apparent effect on Grey Squirrels but until recently was considered invariably fatal to Red Squirrels; the discovery of live seropositive Red Squirrels in Merseyside indicates, however, that some individuals are able to survive exposure to SQPV (Chantrey et al. 2014). In Cumbria, it has been estimated that declines in Red Squirrel populations are 17-25 times faster in areas where SQPV is present in grey populations compared to those where it is not (Rushton et al. 2006). The discovery of an adenovirus which also causes mortality in Red Squirrels is seen as a new emerging threat to their conservation (e.g. Everest et al. 2014). The loss of genetic diversity, driven by the small size and physical isolation of many populations is an additional risk factor to future Red Squirrel persistence (e.g. Barratt et al. 1999; Ogden et al. 2005).

GREY SQUIRREL

Sciurus carolinensis

Introduced to the UK from the late 19th Century to 1938, the Grey Squirrel has become widespread and common throughout England and Wales, southern and central Scotland and Northern Ireland. Information on population trends and status come from the following surveys: NGC, BBS, WBBS, MOR, WMM, LWM, GBW. Results from surveys allowing trend analysis indicate stable or increasing populations of Grey Squirrels over the period covered by the TMP (1995-2002), and the 2009 update recorded a more rapid increase in the ten years to 2007. Trends from the NGC estimate a 97% increase (95% confidence intervals 44 to 160%) between 1961 and 2009. Country-level trends are also available for Grey Squirrel, and the increase in England is estimated as 97% (54 to 160%). In Wales the bag index was initially stable throughout the 1960-80s, but a significant increase of 88% (13 to 182%) was seen between 1995 and 2009. In Scotland there were very few records of Grey Squirrel in the NGC before 1977, but there was a 205% increase (142 to 369%) between 1984 and 2009 as this species expanded northwards. There were insufficient data to calculate trends for Northern Ireland but two large-scale surveys in 1995-6 and 2002 showed Grey Squirrels continuing to spread, being detected at an additional 14 sites (out of a total of 80 surveyed; O'Neill & Montgomery 2003).

The population trends for this species reflect a continued expansion throughout UK as they replace the niche filled by Red Squirrels. However, in Ireland, populations of Grey Squirrels in the midland counties covering an area of approximately 9000km² appear to have crashed and Red Squirrels have been observed for the first time in 30 years. A strong negative correlation between Grey Squirrels and Pine Martens, whose populations have increased in Ireland, was suggested as a contributory factor (Sheehy & Lawton 2013). If this association is indeed causal, it is not clear whether it is predation by Pine Martens, which the available evidence suggests is low, or whether this could be the result of sub-lethal behavioural responses to the presence of Pine Martens depressing Grey Squirrel populations (Sheehy & Lawton 2013).



COMMON RAT

Rattus norvegicus

(also called Brown or Norway Rat)

Introduced to the UK in the 16th Century, the Common Rat is widespread and common throughout the UK. Information on population trends and status come from the following surveys: NGC, BBS, WBBS, WMM, EHCS, GBW. Results from surveys allowing trend analysis indicate a long term increase over the last 25 years with a more rapid increase in the ten years to 2007 (Tracking Mammal Partnership 2009). Trends from the NGC estimate a 95% increase (95% confidence intervals 33 to 164%) between 1961 and 2009. Country-level trends are also available for the Common Rat and the increase in England is estimated as 104% (35 to 191%). In contrast, the bag index in Wales declined by 81% (-39 to -93%) between 1961 and 2009. In Scotland there was a non-significant increase of 110% (-26 to 511%) between 1961 and 2009, and there were insufficient data to calculate trends for Northern Ireland.



Densities of Brown Rat are positively associated with that of humans (e.g. van Adrichem et al. 2013), and it is this association, their generalist diet and their adaptability to urban environments that has driven expansions in their distribution and abundance. Therefore it is likely that increases in the human UK population and concomitant urban expansion are contributory factors in increasing Brown Rat populations, although we were unable to find any specific studies to support this suggestion.

SHIP RAT

Rattus rattus

Ship rats have been present in the UK since the Roman times. Once abundant they are thought to have been displaced by Brown Rats and there is now only one known population on the Shiant Islands in Scotland (230- 400 individuals; MacDonald et al. 1997), whilst they are considered near extinct in the rest of the UK. Ship rat populations have been declining since the introduction of common rates in the 18th Century and improvements in rodent control and hygiene in buildings and on ships have likely further contributed to its decline (Harris et al. 1995).

RED FOX

Vulpes vulpes

Information on population trends and status come from the following surveys: NGC, BBS, WBBS, MOR, WMM, LWM, GBW. Fox populations are thought to have increased in number and range throughout the 20th Century but the rate of increase has now stabilised. Trends from the NGC estimate a 203% increase (95% confidence intervals 130 to 290%) between 1961 and 2009, and a 11% increase (1 to 21%) in the period 1995 to 2009. Country-level trends are also available for Red Fox, and the increase in England is estimated as 258% (171 to 423%) between 1961 and 2009. In Wales, however, there has been no significant change in the bag index over this period (24%, -62 to 316). This contrasts with the BBS and MOR, both of which indicate increases in Wales in the early 2000s. In Scotland there was an increase of 150% (50 to 262%) over the whole period of the NGC (1961 to 2009), but a significant decline between 1996 and 2009 (-15%, -3 to -29%). There were insufficient data to calculate trends for Northern Ireland.



Factors governing the density of Red Foxes and their demographic parameters are an issue of considerable debate and study. Whilst some have proposed that densities are primarily a function of habitat and resources and that culling has little impact on Fox populations at a regional level (e.g. Harris et al. 1995; Baker & Harris 1997; Baker & Harris 2006), others have argued that culling can have substantial impacts on populations, both at local and regional scales (e.g. Heydon & Reynolds 2000a; Heydon & Reynolds 2000b). Following the hunting ban during the foot-and-mouth outbreak in 2001, Baker et al. (2002) found no evidence of increased Fox numbers, although these conclusions have been disputed by others (Aebischer et al. 2003; see also reply from Baker et al. 2003). A review of Fox populations in their native and introduced range concluded that despite 70 years of published studies weaknesses in the available datasets meant that quantifying the effects of harvesting, density and weather on life history rates such as fecundity and survival was not possible (Devenish-Nelson et al. 2013). On a continental scale, Barton & Zalewski (2007) suggest that variation in density in Europe and Asia is best explained by winter temperature and seasonality, with densities decreasing with declining winter and summer temperatures, and duration of snow cover.

Fluctuations in Fox populations have also been attributed to changes in numbers Field Voles, one of their key prey species (Hewson 1984), feeding by humans in urban areas (Baker et al. 2000), and interspecific competition with Badgers (Trewby et al. 2008). The reduction of Badgers as part of the Randomised Badger Culling Trial resulted in increased Fox densities of 1.6-2.3 km² in those areas where Badger numbers were reduced (Trewby et al. 2008), a finding perhaps explained through competition for resources between the two species (e.g. Macdonald et al. 2004b). Outbreaks of sarcoptic mange can considerably reduce local Fox densities where they occur taking 15-20 years for numbers to recover; the last large outbreak in the UK occurred in the 1990s reducing urban Fox densities in Bristol by more than 95% (Soulsbury et al. 2007).

PINE MARTEN

Martes martes

Following persecution in the 19th Century Pine Marten populations were restricted to a small population in northern Scotland and smaller fragmented populations were also reported from Wales and northern England (Langley & Yalden 1977). A series of surveys in the late 1950s (Lockie et al. 1964), 1980s (Velandar 1983), 1990s (Balharry et al. 1996) and 2010s (Croose et al. 2013, 2014) have documented the recolonisation of much of its former range within Scotland and in 2013 it was detected in eastern Dumfries and Galloway, close to the border with England. There are no population trends available for Pine Marten in the UK.



The recovery of Pine Marten across much of their former range in Scotland has been attributed to reductions in persecution and widespread reforestation, backed up by full legal protection since 1988 (Croose et al. 2013).

STOAT

Mustela ermine

Information on population trends and status come from the following surveys: NGC, BBS, WBBS. Long-term data from the NGC shows an increase in the Stoat bag index of 117% (95% confidence intervals 75 to 173%) between 1961 and 2009. Following a dip in the index in the 1980s, populations have recovered and a 28% increase (12 to 42%) was recorded in the period 1995 to 2009. This is supported by evidence from BBS over the same period. Whilst data from WBBS indicated a significant decline between 1998 and 2003, Newson et al. (2005) recommend that data for Stoat from this survey should be treated with caution. Country-level trends are also available for Stoat, and the increase in England is estimated as 150% (88 to 228%) between 1961 and 2009. In Wales, however, while there has been no significant change in the bag index between 1961 and 2009, a decline of 35% (-2 to -71%) was detected between 1995 and 2009. Overall, there has been little change in the bag index for Stoat in Scotland, although a decline in the 1980s was followed by an increase leading to a positive trend of 51% (11 to 96%) between 1984 and 2009. There were insufficient data to calculate trends for Northern Ireland. Strong correlations between gamekeeper trapping effort and bags of Stoat highlight the need to consider trapping effort in the National Gamebag Census, however (McDonald & Harris 1999).



Populations of Stoat (and Weasels) respond to fluctuations in their key prey, Rabbits and small mammals respectively (King 1980; King et al. 2007). The reliance of Stoats on Rabbits was illustrated by population crashes that followed the Myxamatox outbreak in Rabbits between 1953 and 1955 (King 1980). The impact of culling on Stoat (and Weasel) populations is thought to be short-lived and local due to high rates of immigration into culled sites from surrounding areas (McDonald & Harris 2002).

WEASEL

Mustela nivalis

Information on population trends and status come from the following surveys: NGC, BBS, WBBS. Long-term data from the NGC indicate a decline in weasel populations, with the bag index more than halving between 1961 and the late 1980s (decline estimated as -37%; 95% confidence intervals -22 to -52% between 1961 and 2009), however McDonald & Harris (1999) suggest that this decline may be due to decreased trapping effort by gamekeepers over this period. Since 2000, the bag index has started to increase and the trend between 1995 and 2009 shows a 51% increase (23 to 80%). This is supported by evidence from BBS over the same period. Whilst data from WBBS indicated a significant decline between 1998 and 2003, Newson et al. (2005) recommend that data for Weasel from this survey should be treated with caution. Country-level trends are also available for Weasel, with an overall decline of -37% (-19 to -53%) between 1961 and 2009 in England but an increase of 73% (31 to 122%) between 1995 and 2009. There has been no detectable change in Weasel populations in Scotland since 1961 (-16%, -43 to 32%), whilst in Wales the decline between 1984 and 2009 is estimated as -75% (16 to -88%) although these changes however are not statistically significant. There were insufficient data to calculate trends for Northern Ireland.



Populations of Weasel (and Stoat) respond to fluctuations in their key prey, Rabbits and small mammals respectively (King 1980; King et al. 2007). Following the Myxomatosis outbreak in Rabbits between 1953 and 1955 (King 1980), Weasels populations increased sharply, in contrast to those of Stoats, as vegetation suppressed by Rabbits flourished and supported larger populations of small mammals (King et al. 2007). The impact of culling on Weasel (and Stoat) populations is thought to be short-lived and local due to high rates of immigration into culled sites from surrounding areas (McDonald & Harris 2002).

POLECAT

Mustela putorius

The Polecat was heavily persecuted in the 19th Century leading to very restricted distribution in mid-Wales by 1915. Populations have since recovered to an extent, with a widespread distribution in Wales and England. A number of reintroductions have been carried out in Cumbria, the East Midlands, southern England and the West Highlands in Scotland. The Vincent Wier Trust (VWT) conducted two national polecat surveys during the 1990s and 2004-2006 which showed a continued expansion of Polecat in England and Wales. A third survey is currently underway. Polecats may hybridise with domesticated Ferrets in the wild (Polecat-Ferrets), and it has been suggested that the Ferret is a domesticated variant of the wild Polecat (Birks & Kitchener 1999). The NGC provides trend information for Polecats (caught unintentionally in traps set for Stoat and rats), although these are likely to include Ferrets and Polecat-Ferrets; whilst the bag index has increased by 176% (-58 to 1341) between 1961 and 2009 the errors are so large that no significant change is



detectable. Country-wide trends show a similar pattern to those described at the UK level. The TMP 2009 update reports indications of increases in distribution and abundance between 1992 and 2007. The Polecat is naturally absent from Ireland.

After the First World War, direct persecution of Polecats was greatly reduced which facilitated increases in abundance and recovery of part of their former range (Birks 2000). This expansion was probably also aided by recovering populations of their main prey, rabbits, following an outbreak of myxomatosis in the mid 1950s, the banning of the gin trap in 1958, and a number of re-introductions (Birks 2000). Recent analyses have indicated evidence of extensive introgressive hybridisation with feral ferrets highlighting the importance of the Welsh Polecat population in order to ensure the genetic identity of this species in Britain (Costa et al. 2013).

FERAL FERRET

Mustela furo

There are no population trends available for feral Ferret in the UK. Only three ferrets were seen during the VWT's Polecat and Mink Abundance Monitoring programme in 2002, and none in 2003.



AMERICAN MINK

Mustela vison

Information on population trends and status come from the following surveys: NGC, WBBS. Introduced to the UK in the 1920s, escapees from fur farms had established in the wild by the 1950s and then spread rapidly. Long-term trends from the NGC indicate a significant increase in bag records between 1962 and 2009 (163%; 95% confidence intervals 16 to 333%), with the main period of increase between 1962 and 1976. Numbers since then, however, have started to decline with a -49% change (-40 to -57%) recorded between 1984 and 2009. Country-level trends are also available for American Mink with England recording a 226% increase (17 to 450%) between 1962 and 2009, but a 33% decrease (-9 to -48%) between 1984 and 2009. Adequate data for Scotland have only been available since 1976 and the long-term trend up to 2009 is of a 61% decline (-37 to -75%). Adequate data for Wales have only been available since 1995 and there has been no detectable change up to 2009. There were insufficient data to calculate trends for Northern Ireland.



Populations of American Mink are subject to culling efforts in many European countries due to the impact they can exert on many prey populations (e.g. Craik 1998, Melero et al. 2010; see also [management section](#)). Whilst culling operations can reduce densities considerably eradication of mainland populations is hampered by immigration from surrounding areas and density-dependent fecundity such that birth rates increase in response to declining populations (Melero et al. 2010). It has been suggested that the recovery of Otter populations throughout much of their UK range has contributed to recent declines of American Mink through intraspecific competition (Bonesi &

Macdonald 2004; Bonesi et al. 2006). The most direct evidence of this was a release of captive-bred Otters into the Upper Thames catchment in England (Bonesi & Macdonald 2004); at three release sites occupancy by mink decreased by 23-77%, whilst at a control sites levels remained the same.

BADGER

Meles meles

Information on population trends and status come from the following surveys: BBS, WBBS, MOR, WMM; LWM, GBW. In addition two national surveys were conducted in 1985- 1988 and 1994-1997; this indicated a 24% increase in the number of social groups (commonly used as a population metric for this species) and a 75% increase in the total abundance between these two time periods (Wilson et al. 1998). Confidence intervals for these increases are not available. There was considerable variation between regions with small declines in some areas and large increases, for example in the West Midlands (86%) and South-west England (23%), in others (Wilson et al. 1998). A third survey conducted in England and Wales in 2011-2013 (Judge et al. 2014) found that whilst there had been little change in the number of Badger social groups since the 1980s in Wales, numbers in England had increased by 103% (95% confidence intervals 83 to 123%). From the other surveys that allowed trend analysis, BBS indicated an upward trend in badger numbers (1996-2002) with no change recorded by WBBS (1998-2003).



Prior to the Badgers Act 1973, Badgers were routinely culled as part of a predator control strategy by landowners and gamekeepers and whilst, they did not undergo the range contractions seen in some other similarly controlled carnivores, they were considered rare by the latter half of the 19th Century (Wilson 1998). Their legal protection was strengthened in the Wildlife & Countryside Act 1981 and the Badgers (Further Protection) Act 1991. Wilson (1998) Judge et al. (2013) have ascribed the increases in Badger numbers documented in surveys since the 1980s to reduced persecution, with Wilson (1998) showing that across Britain regions with the highest percentage of setts showing signs of digging were those where population growth was lowest. Similarly, in Northern Ireland, Sadler & Montgomery (2004) found a negative correlation between adult group size and level of disturbance at setts. The single largest cause of recorded death for Badgers is traffic collisions (Clarke et al. 1998), which have been estimated to kill in the region of 50,000 Badgers per year (Harris et al. 1995). Regions with a high density of roads and traffic levels may also present a barrier to Badger movement in the landscape (Clarke et al. 1998). Whilst the overall increase in Badger numbers in the UK indicates that mortality and barriers imposed by the traffic network does not appear to be impacting on Badger populations as a whole, Skinner et al. (1991) highlight the potential for roads to impact on Badgers at a local scale, particularly where populations were already low due to other reasons.

OTTER

Lutra lutra

Trapping by gamekeepers and hunting for sport during the 18th and 19th Century led to wide fluctuations in population abundance, and poisoning by organochlorine pesticides led to sharp declines after 1957, particularly in England and south Wales (Chanin & Jeffries 1978). However, there has been a continual increase in Otter populations over the last 25 years with substantial range expansion and populations increasing in abundance. Five National surveys in England have been conducted since the late 1970s with the most recent one estimating a 915% increase in the number of sites with positive Otter signs since the surveys began, and an increase of 62% since the survey in 2000-2002 (Crawford 2010). In Wales an increase of 268% was reported between 1978 and 2004 (Jones & Jones 2004), whilst in Scotland 92% of survey sites held positive signs for Otter, up from 57% in the 1970s (Strachan 2007). In Northern Ireland, a 10% decline was reported between the 1980-1981 and 2001-2002 surveys but since then has increased by 27% (Preston et al. 2004; Preston & Reid 2011). Signs of Otter are recorded as part of WBBS but no significant change has been detected between 1998 and 2003.



The cause of the decline, and subsequent recovery, of Otter populations in the UK is still a subject of debate. Whilst it seems clear that poor water quality and exposure to toxins were in some combination to blame for the population crash in the 1950s, quantifying the relative effects is problematic and authors disagree on whether dieldrin, PCBs or another toxin was the prime culprit (e.g. Chanin & Jeffries, 1978; Mason & Macdonald 1994; Kruuk & Conroy 1996; Smit et al. 1998). Extensive pollution in waterways caused by sewage effluent and industrial discharges was also sufficiently high in parts of the UK by the 1980s for rivers to be classed as grossly polluted and devoid of fish (Strachan 2007). Following the bans of dieldrin and PCBs in the 1980s and the introduction of UK and European legislation that led to marked improvements in water quality, Otter populations have largely recovered their previous range. However, there are still areas such as Devon where Otters are absent from reaches with poorer quality habitat and of lower water quality suggesting the recovery process is still in progress (Bedford 2009).

WILDCAT

Felis silvestris

Wildcats were once widespread within Great Britain but are now restricted to the northern half of Scotland, with estimates that there may be as few as 400 “pure” individuals left (Yamaguchi *et al.* 2004). Wildcats may have been hybridising with feral cats for about 2,000 years and many of the hybrids are difficult to distinguish from pure Wildcat so conducting reliable surveys is extremely problematic (Balharry & Daniels 1998). Data from the National Gamebag Census are available only for the period 1971 to 1987 (during which there was no significant change), after which it was given protection under the Wildlife & Countryside Act (1988). The most recent survey reports Wildcat records are most numerous in Aberdeenshire, Inverness-shire, Ardnamurchan and Morvern (Davis & Gray 2010).



Whilst active persecution and habitat loss have been cited as factors in the historic decline of Wildcat (Macdonald et al. 2004a), the key threats to the persistence of this species in the UK is introgression with domestic cats and the consequences for the genetic composition of the remaining populations which are small and restricted (Macdonald et al. 2004a). Silva et al. (2013) also highlight the importance of food and habitat availability for the remaining populations, with probable Wildcat occurrence (observations of individuals possessing all the key pelage criteria identified by Kitchener et al. 2005) being most likely to occur in areas containing large grasslands with rabbits and high rodent diversity. Previous studies on Wildcat in Central Europe have also identified the importance of habitat heterogeneity (Klar et al. 2008), suggesting that habitat loss and agricultural intensification are likely to have contributed to the decline of this species.

FERAL / DOMESTIC CAT

Felis catus

The number of domestic cats in the UK in 2007 was estimated at just over 10 million (Murray *et al.* 2010). The 2009 TMP update suggested a decline of 24% in domestic/feral cats over last 25 years prior to 2009, and a 16% decline in the ten years prior to 2009 (confidence intervals not available). However, if real this decline is likely to reflect changes in feral cat populations only as domestic cat population estimates show a steep increase in cat ownership in the past fifty years, doubling since the mid 1960s (Pet Food Manufacturing Association 2014).



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4.1 Review of population trends for raptor predators of wild birds

RED KITE

Milvus milvus

Feeding habits

A generalist predator and scavenger, for which young, and sometimes adult, wild birds form part of the diet.

Distribution and abundance in Scotland

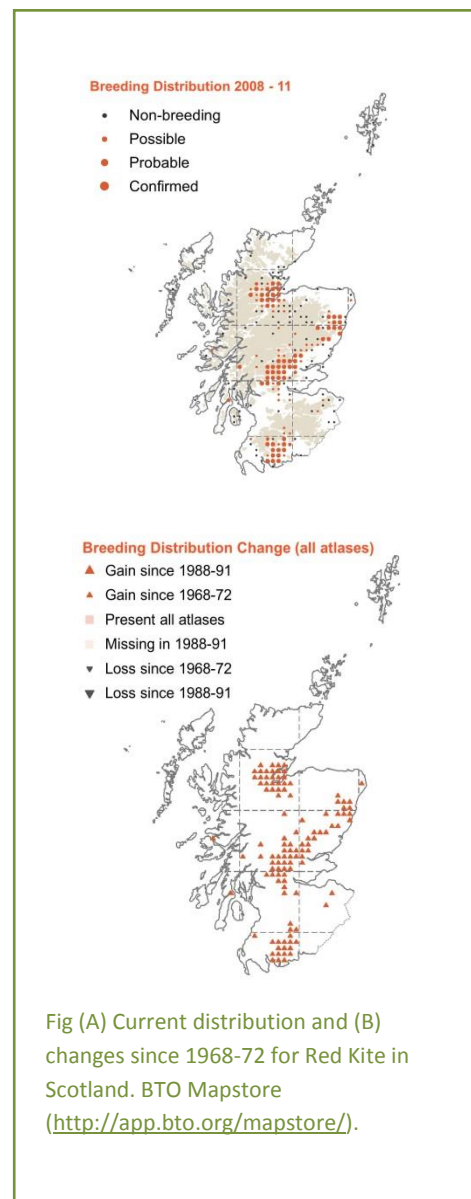
Formerly widespread in Scotland, this species was driven to extinction in the late 1800s. The re-introduced Scottish population is currently confined to four main areas centred on: the Black Isle near Inverness; Aberdeenshire; Central Scotland; and Dumfries & Galloway; Fig. A). Releases by a joint RSPB and SNH project took place on the Black Isle (89 birds between 1989 and 1993), in Central Scotland (103 birds between 1996 and 2001), Dumfries and Galloway (104 birds between 2001 and 2004) and, most recently, in Aberdeenshire (99 birds between 2007 and 2009). In 2007-11 the species was thought to breed in 111 10-km squares in Scotland.

Recent population trends in Scotland and geographical variation

The Scottish population has shown sustained growth since reintroductions began in 1989, at both national and regional scales (Figs B, C & D; Roos *et al.* 2015). The rate of increase has been slowest for the Black Isle sub-population, because of poor survival rates of first year birds, largely due to persecution (Smart *et al.* 2010).

Drivers of population change

The Scottish breeding population became extinct in the late 1800s due to widespread killing by sporting estates and the taxidermy trade (Forrester *et al.* 2007). Reintroductions during the twenty-year period 1989-2009 were responsible for its successful re-establishment. Growth of the northern Scotland sub-population is considered to be limited by illegal killing (Smart *et al.* 2010) and (accidental) rodenticide poisoning may also be contributing to mortality in Scotland, more widely than has been demonstrated to date (Hughes *et al.* 2003); the latter has been shown to cause high levels of mortality in Red Kites elsewhere (Coeurdassier *et al.* 2014).



UK, EU and global status and trends

Re-expansion of the remnant Welsh population took place from the late 1960s and has continued to the present, alongside re-colonisation of England following re-introductions in the Chilterns from 1989 and three other areas since 1995 (Balmer *et al.* 2013). The range in England and Wales expanded by 1644% between 1968-72 and 2007-11, with a net gain of 559 10-km squares. Small populations are now also re-established in Ireland following reintroductions in two areas since 2007 (refer to [Mapstore maps](#)).

BOCC4 status = **Green**

Birds Directive status = Annex 1

BirdLife EU status = NT

IUCN global status = NT

Demographic knowledge

Demographic information is available from the [SRMS annual reports](#) and [BTO BirdFacts](#). Productivity of the three largest sub-populations has not shown any long-term trend (Roos *et al.* 2015). Survival rates are available from Smart *et al.* (2010).

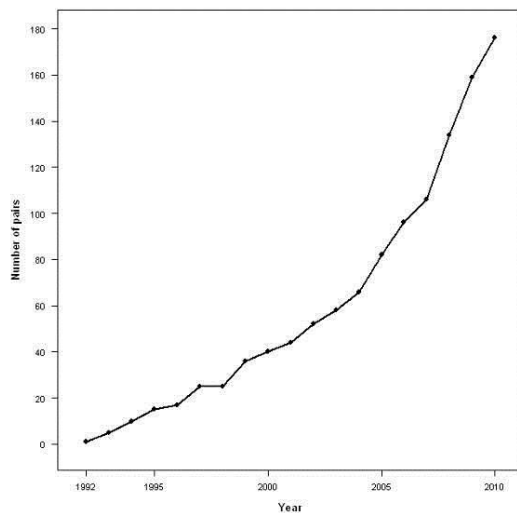


Fig. C Trends in the number of breeding pairs of Red Kites in the whole of Scotland for the years 1992-2010. (Source: [Roos *et al.* 2015](#) from RSPB data)

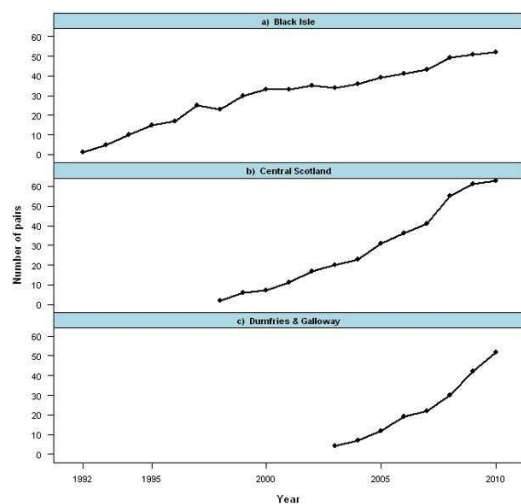


Fig. C Trends in the number of breeding pairs of Red Kites in the three areas of Scotland where the reintroduced species had been breeding for more than five years during the period 1992-2010.
 (Source: [Roos et al. 2015](#) from RSPB data)

WHITE-TAILED EAGLE

Haliaeetus albicilla

Feeding habits

An apex predator and scavenger, regularly taking a range of adult and young birds as prey, as well as mammals and fish.

Distribution and abundance in Scotland

Probably previously widespread across Scotland, the species was driven to extinction in the early 1900s. The re-established Scottish population is largely confined to the western part of Scotland (Fig. A), although recent reintroductions have also occurred in the east (Fife). Releases of white-tailed eagles in Scotland began in 1975, with 82 birds released on Rum (1975-1985), 58 in Wester Ross (1993-1998), and 85 in Fife (2007-2011) (Evans *et al.* 2009; RSPB 2012). In 2007-11 the species thought to breed in 92 10-km squares in Scotland, in the Outer Hebrides, Wester Ross, Skye & the Small Isles and north Argyll (centred on Mull). The Fife birds had not bred by the end of the Bird Atlas fieldwork in 2011 but have done so subsequently.

Recent population trends in Scotland and geographical variation

The Scottish population has increased nationally and regionally showing a steady population growth and range expansion (Figs B, C & D; [Roos *et al.* 2015](#)).

Drivers of population change

This species became extinct in Scotland in the early 1900s, due to killing by gamekeepers and shepherds, and egg collecting (Forrester *et al.* 2007). Following failed reintroductions of small numbers of birds from the late 1950s (Forrester *et al.* 2007), further reintroductions between 1975 and 2011 resulted in successful re-establishment of the breeding population in both west and east Scotland. Showing slow growth in the early years of reintroduction, the population is now expected to show rapid growth (Forrester *et al.* 2007), which may bring the species increasingly into conflict with farming and sporting estate interests. Illegal poisonings of the species have been recorded in recent years, as well as incidents of egg collecting; evidence of chemical pollutants in eggs have also been found but not at levels thought to induce infertility (Forrester *et al.* 2007). No evidence of competition with Golden Eagles has been found to date (Whitfield *et al.* 2013).

UK, EU and global status and trends

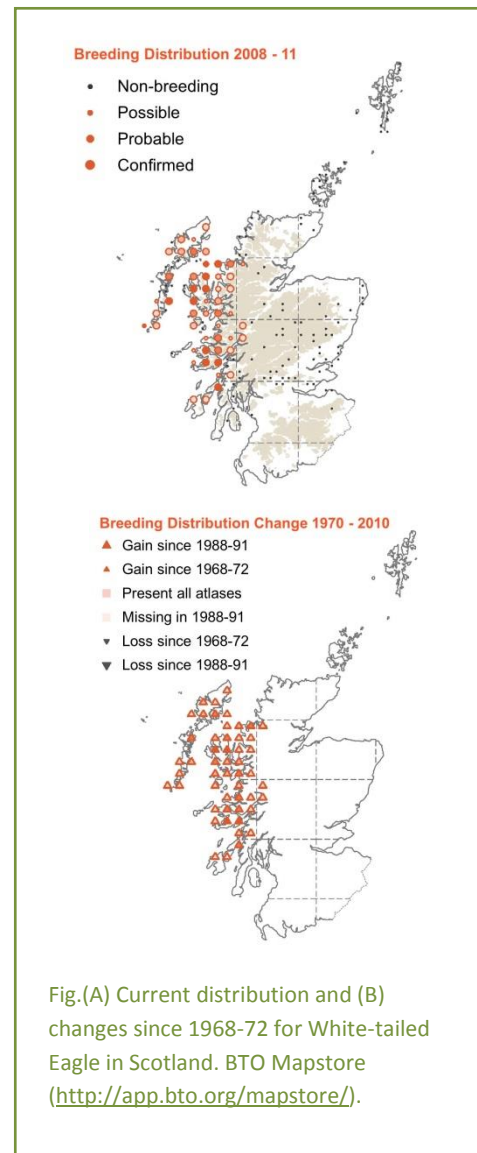


Fig.(A) Current distribution and (B) changes since 1968-72 for White-tailed Eagle in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

There are no breeding birds in England or Wales. Releases in County Kerry, Ireland during 2007-11 (100 birds) led to a first breeding attempt in 2012 and first fledging (two pairs) in 2015 ([Golden Eagle Trust website](#)).

BOCC4 status = **Red**

Birds Directive status = Annex 1

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is available from the [SRMS annual reports](#) and [BTO BirdFacts](#). Productivity has not shown any long-term trend either nationally or regionally ([Roos et al. 2015](#)).

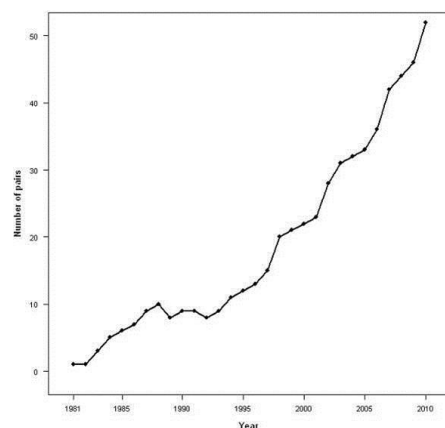


Fig. C Trends in the number of breeding pairs of white-tailed eagles in the whole of Scotland for the years 1981-2010. (Source: [Roos et al. 2015](#) from RSPB data)

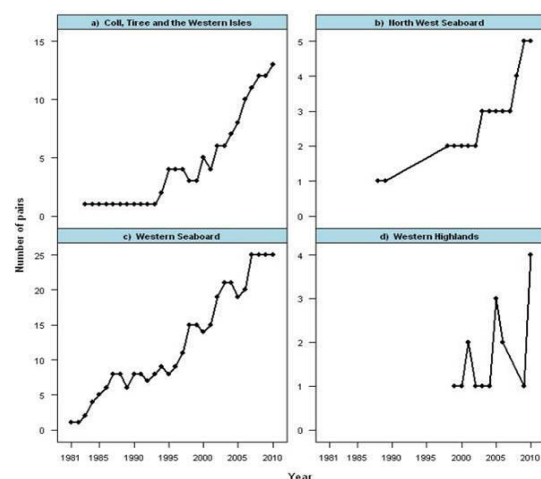


Fig. D Trends in the number of breeding pairs of white-tailed eagle in the four NHZs holding the majority of the Scottish breeding population for the years 1981-2010. (Source: [Roos et al. 2015](#) from RSPB data)

HEN HARRIER

Circus cyaneus



Feeding habits

A generalist predator, for which small- to medium-sized adult birds and their young form part of the diet, alongside small mammals.

Distribution and abundance in Scotland

This open-country species breeds in heather moorland, young forestry plantations and, more rarely, on extensive farmland, and is present across Scotland, including on Orkney, the Uists and Inner Hebrides, mainland Argyll, Caithness, parts of the Highlands and locally in the Southern Uplands (Figs A & B). It is largely absent from breeding in Shetland, Harris & Lewis, most of the north-west Highlands, the eastern lowlands, central belt and large parts of southern Scotland. In 2007-11 it was thought to breed in 376 10-km squares.

Recent population trends in Scotland

Population trends are available from four SCARRABS surveys : 1988/89 (Bibby & Etheridge 1993) 479 territorial pairs; 1998 (Sim *et al.* 2001) 436 pairs; 2004 (Sim *et al.* 2007) 633 pairs (95% confidence intervals 563-717; 32% significant increase from 1998); and 2010 (Hayhow *et al.* 2013) 505 (95% confidence intervals 417-612; 20% but non-significant decline from 2004). A slightly updated population estimate apportioned to individual NHZs is also available ([Wilson *et al.* 2015](#)). The Bird Atlas shows a net increase in range of the species between 1968-72 and 2007-11 of 16% (net gain of 53 10-km squares) but substantial geographical variation in the pattern of gains and losses (Fig. C) and decreases in abundance across much of the range in mainland Scotland (Fig. D).

Geographical variation in Scottish trends

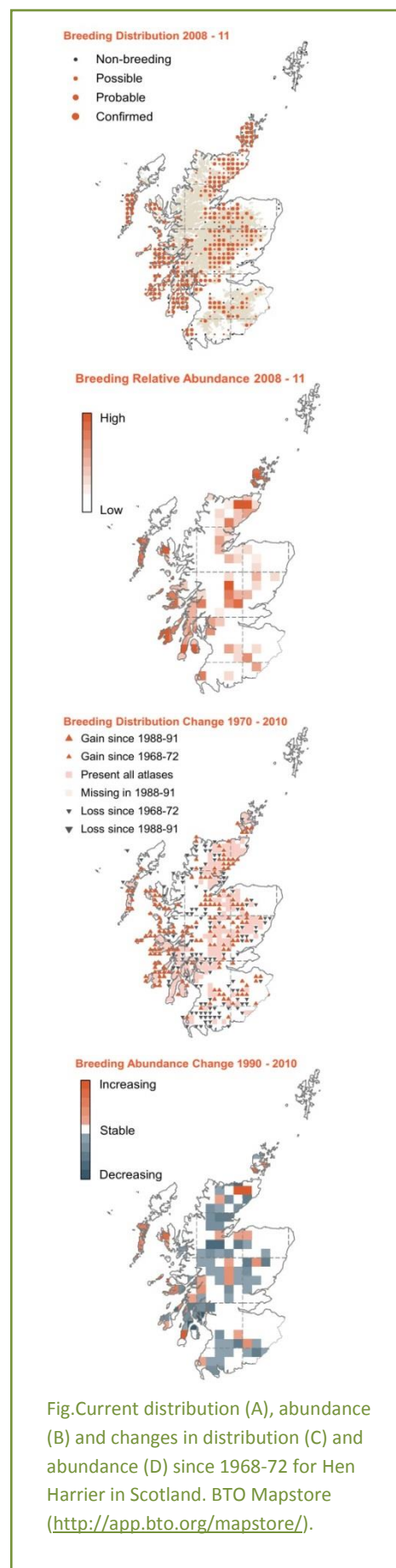


Fig. Current distribution (A), abundance (B) and changes in distribution (C) and abundance (D) since 1968-72 for Hen Harrier in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

The national surveys (Sim *et al.* 2007; Hayhow *et al.* 2013) have presented changes through time for six areas of Scotland (**Error! Reference source not found.**). The trends lack any consistency between or across regions, reflecting the mixed fortunes of this species since the late 1980s and the differential effects through time of the varying drivers of population change.

Drivers of population change

For five NHZs of Scotland (Central Highlands, Cairngorm Massif, Northeast Glens, Western Southern Uplands and Inner Solway, and Border Hills) there is strong evidence that illegal persecution is limiting populations by causing the failure of a majority of breeding attempts (Fielding *et al.* 2011). The decline from the 1970s to the late 1990s is also well researched and understood to have been caused by intensification of grazing reducing the availability of rough grass (and thus vole prey), the consequences of which have been reversed by introduction of appropriate habitat management prescriptions (reductions in sheep grazing) since 2002 (Amar *et al.* 2003, 2005, 2011a). It is suspected that a shortage of food and/or suitable nesting habitat is limiting populations in two other NHZs (the Peatlands of Caithness and Sutherland, and Northern Highlands) but this has not been tested via specific research (Fielding *et al.* 2011). Changes in the extent and type of afforestation are also likely to affect Hen Harrier populations in Scotland, probably in a complex manner because their influence depends not only on the extent and nature of the forestry itself but also on the availability of surrounding land suitable for foraging (e.g. Wilson *et al.* 2012).

UK, EU and global status and trends

The Welsh population doubled between 1998 and 2010, while the Northern Ireland population increased six-fold between the late 1980s and 2004 but since shows evidence of decline (**Error! Reference source not found.**); Hayhow *et al.* 2013). The English population is understood to be constrained to a level far lower than that which could be supported based on suitability of habitat and climate, as a result of illegal killing and disturbance (Anderson *et al.* 2009; Fielding *et al.* 2011; Hayhow *et al.* 2013).

BOCC4 status = **Red**

Birds Directive status = Annex 1

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

The most recent productivity and survival information is available in Fielding *et al.* (2011; revised version expected soon) and the [SRMS annual reports](#). Trends in productivity parameters since 2003 for three to five Scottish NHZs did not show any consistent trends ([Roos *et al.* 2011](#)).

Table 6. Numbers of territorial pairs of Hen Harrier in six areas of Scotland, and the rest of the UK, and changes between years, as estimated by four national surveys in 1988/89, 1998, 2004 and 2007 (from Sim *et al.* 2007 and Hayhow *et al.* 2013).

Region/ COUNTRY	Territorial pairs				Change between survey years (%)				
	1988/89	1998	2004	2010	1988/89 to 2004	1998 to 2004	1998 to 2004 same squares (sample size)	2004 to 2010	2004 to 2010 same squares (sample size)
Orkney	71	34	74	74	4	118		0	1.4 (9)
Hebrides	n/a	24 (11- 43)	48 (45- 54)	48 (44- 56)	n/a	100 (88- 125)*	100 (11)	0	-4.9 (20)
North Highlands	85 (21- 165)	30 (13- 53)	102 (72- 137)	59 (38- 87)	20 (-15 to 61)	240 (140- 357)*	20 (16)	-42*	-38.5 (9)
Southern Uplands	80 (20- 152)	117 (97- 153)	73	57 (49- 74)	-9	-38*	-25 (31)	-22	-35.0 (27)
East Highlands	109 (61- 158)	82 (64- 99)	65 (54- 76)	115 (65- 183)	-40 (-50 to -30)*	-21 (-34 to -7)	-38 (45)	77	-23.8 (36)
West Highlands	148 (73- 236)	159 (107- 218)	234 (191- 285)	194 (110- 281)	58 (29- 93)*	47 (20- 79)*	34 (39)	-17	-27.7 (21)
ALL SCOTLAND	479	436	633 (563- 717)	505 (418- 612)	37* (excluding Orkney)	39* (Excluding Orkney)	—	-20	-16.0 (122)
ENGLAND	18 (in 1990)	19	11	12	-39	-42	—	9.1	
WALES	27	28	43	57	59	54	—	32.6	
NORTHERN IRELAND	10	38	63 (58- 68)	59	530*	66*	—	-6.3	

GOSHAWK

Accipiter gentilis



Feeding habits

An apex predator, regularly taking a wide variety of adult birds and their young, as well as a range of other prey.

Distribution and abundance in Scotland

Associated with extensive forests in many areas, this species was thought to breed in 148 10-km squares in 2007-11, mostly across southern Scotland and in the north east (Fig. A). Goshawk is absent as a breeding species from the Northern and Western Isles and most of north and western Scotland north of the Southern Uplands. The species is thought to be under-recorded in Scotland, such that the 130+ breeding ranges known in 2013 (Challis et al. 2014) is likely to be a considerable underestimate (Wilson et al. 2015).

Recent population trends in Scotland

Driven to extinction in Britain in the late 1800s due to killing and deforestation, it is thought that reintroduction took place in the 1960s and 1970s through accidental and deliberate releases (Marquiss & Newton 1982). Since the late 1960s the Scottish range has expanded by 543%, with a net colonisation of 125 10-km squares (Fig. B), mostly in southern and north-east Scotland. The overall change in relative abundance in Scotland between 1988-91 and 2007-11 from the Bird Atlas survey was +123%.

Geographical variation in Scottish trends

In a north-east Scotland study area, recolonization occurred in 1973 and the population remained below 10 pairs until 1994, after which rapid increase occurred to 48 pairs by 2011 (Marquiss *et al.* 2003; Marquiss 2011; [Roos *et al.* 2015](#)). First successful breeding in the Borders occurred in 1977, and the population rose to 87 pairs by 1996 (Marquiss *et al.* 2003). Provisional trend information from a study in south-west Scotland shows a steady increase since 2003 but suggests some recent decline in a further study area spanning parts of the Border Hills and south Lothian ([Roos *et al.* 2015](#)).

Drivers of population change

Persecution is considered to have contributed substantially to past extinction (Hollom 1957) and to still be limiting population expansion in at least some areas (Marquiss *et al.* 2003). Re-afforestation, and forestry practices leading to more mature growth would be expected to benefit the species.

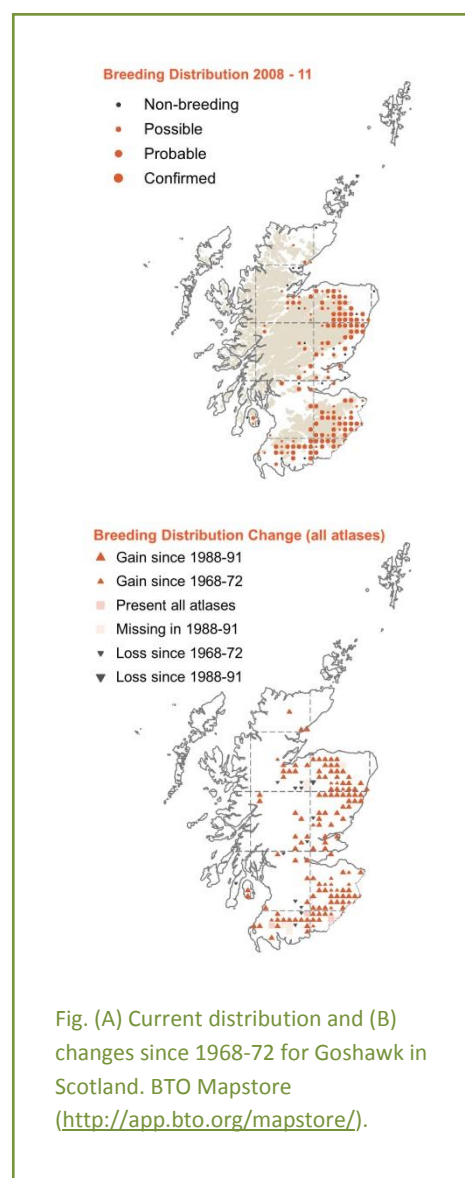


Fig. (A) Current distribution and (B) changes since 1968-72 for Goshawk in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

UK, EU and global status and trends

The recovery of the breeding population (range and abundance) in Scotland has also occurred across Wales, the North East and other more localised parts of England (Balmer *et al.* 2013; link to [Britain and Ireland atlas maps](#)). Range has increased by 2725% in England and Wales since the late 1960s (a net gain of 327 10-km squares occupied). Goshawk is still a very rare breeder in Ireland, having colonised since the late 1980s.

BOCC4 status = **Green**

Birds Directive status = n/a

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Recent demographic information is available in the [SRMS annual reports](#) and [BTO BirdFacts](#).

Productivity information from three Scottish study areas has not shown any systematic trend since 2003 ([Roos *et al.* 2015](#)).



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SPARROWHAWK

Accipiter nisus

Feeding habits

A specialist predator of small to medium-sized birds.

Distribution and abundance in Scotland

Widespread as a breeding bird across Scotland, with the exception of the high uplands, Shetland and some of the west coast islands (Fig. A). Most abundant in the south of Scotland, the Central Belt, and along the east coast as far north as the Dornoch Firth, and least abundant in the central highlands, the north and west and the offshore islands (Fig. B). Thought to breed in 689 10-km squares in 2007-11.

Recent population trends in Scotland

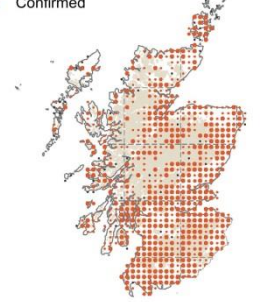
The population reached a low point in the 1960s, probably as a result of the use of organochlorine agricultural pesticides (Prestt 1965, Newton 1986, Newton & Wyllie 1992). The Scottish range has recovered by 16% since the late 1960s, with a net colonisation of 96 10-km squares (Fig. C), mostly in the west and north, Orkney and the Hebrides. The overall change in relative abundance in Scotland between 1988-91 and 2007-11 from the Bird Atlas survey was -5% (i.e. little change overall). A provisional Scottish trend from BBS suggested a possible small decline in the 2000s but cannot be regarded as definitive because the species is currently recorded on fewer survey squares in Scotland than the recommended lower threshold of 30 BBS squares required on an annual basis: a smoothed trend is not produced and statistical significance is not currently tested routinely for this species (Roos et al. 2015).

Geographical variation in Scottish trends

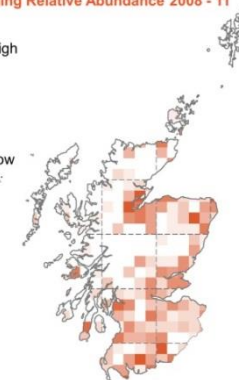
Since the late 1960s, the pattern of range change has varied across Scotland. The NHZs with the largest positive range changes were the Eastern Lowlands (net of 23 colonised 10-km squares), North Caithness & Orkney (15 squares) and Western Seaboard (14 squares), with four

Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed

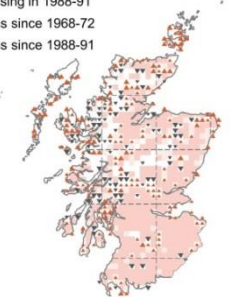


Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

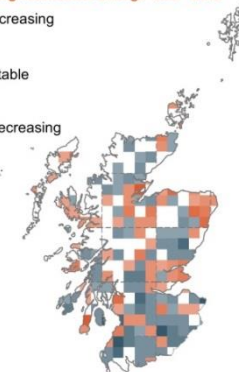
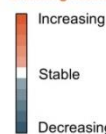


Fig. (A) Current distribution and abundance (B) and changes (C & D) since 1968-72 for Sparrowhawk in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

other NHZs showing a net gain in occupancy of 10 or more squares ([Appendix 11](#)). Changes in relative abundance since the late 1980s have also been variable spatially (Fig. D), with the North East Glens, Western Southern Uplands & Inner Solway and Border Hills showing the most negative changes, and the North East Coastal Plain the most positive. In a 200 km² study area in Dumfriesshire, numbers of Sparrowhawk nests fluctuated only slightly (between 30 and 40 pairs between 1972 and 1991 (Newton 1992) but had declined by one-third by 1995-97 (Newton in Forrester *et al.* 2007). A more recent provisional trend in breeding numbers from one study area in Ayrshire suggested some increase followed by decrease in the number of breeding pairs since 2003 ([Roos *et al.* 2015](#)).

Drivers of population change

Numbers are understood to have been lowered because of control by gamekeepers up to the 1950s and were then reduced still further by secondary poisoning from organochlorine pesticides, reaching population lows in the early 1960s (Newton 1986). Subsequently, as these chemicals were restricted and phased out, the Scottish population is considered to have recovered (with recovery latest in the eastern arable areas), and probably reached a high in the late 1980s (Newton in Forrester *et al.* 2007). The decline in populations, in at least parts of Scotland, since that time may be related to maturation and felling of areas of previously suitable forest (e.g. across southern Scotland) and declines in small songbirds on farmland (Newton in Forrester *et al.* 2007).

UK, EU and global status and trends

The recovery of the breeding range since the 1960s has been greater across (particularly eastern) England than in Scotland; the largest positive changes in relative abundance since the late 1980s have occurred in eastern England and the east of Ireland (Balmer *et al.* 2013; link to [Britain and Ireland atlas maps](#)). Range has increased by 34% in England and Wales since the late 1960s (a net gain of 422 10-km squares occupied) and remained stable overall (-2% change, net loss of 13 10-km squares) in Ireland.

BOCC4 status = **Green**

Birds Directive status = n/a

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Recent demographic information is available in the [SRMS annual reports](#) and [BTO BirdFacts](#).

Provisional productivity information from an Ayrshire study area suggested that clutch size for pairs that laid, fledging success and the number fledged per successful pair all showed signs of decrease since 2003 ([Roos *et al.* 2015](#)).



COMMON BUZZARD

Buteo buteo

Feeding habits

A generalist predator and scavenger, for which young, and sometimes adult, wild birds form part of the diet.

Distribution and abundance in Scotland

Present throughout Scotland, with the exception of Shetland. Most abundant across Southern Scotland, along the eastern lowlands and in Caithness, and least abundant in Orkney, the Outer Hebrides and the highlands of central and north-west Scotland (Figs A & B). Thought to breed in 942 10-km squares in 2007-11.

Recent population trends in Scotland

Since the late 1960s, the species has shown considerable recovery of its range back into the lowlands of southern, central and eastern Scotland, with much of that expansion occurring since the late 1980s (Fig. C). Since the late 1960s the Scottish range has expanded by 28%, with a net colonisation of 257 10-km squares ([Appendix 11](#)). Breeding abundance has increased in most areas since the late 1980s, with the largest increases in the Southern Uplands and lowlands of the east, Central Belt and north east (Fig. D; an overall increase of 23% since 1988-91). The national trend in buzzard breeding abundance (from BBS, Fig. E) showed a sustained and statistically significant increase between 1994 and 2002, but some suggestion of decline since 2002. The overall change in abundance between 1995 and 2013 from BBS was +23% (lower and upper confidence limits -4 to +53%, so not significant over the whole period; Harris et al. 2015). The BBS trend may not be fully representative of change in breeding numbers however, as the methods do not allow breeding pairs to be distinguished from non-breeding 'floaters', numbers of which may not vary in direct proportion to the numbers of breeding pairs in a population ([Roos et al. 2015](#)).

Geographical variation in Scottish trends

Since the late 1960s, range (at 10-km square resolution) has remained largely constant in about half of Scottish NHZs,

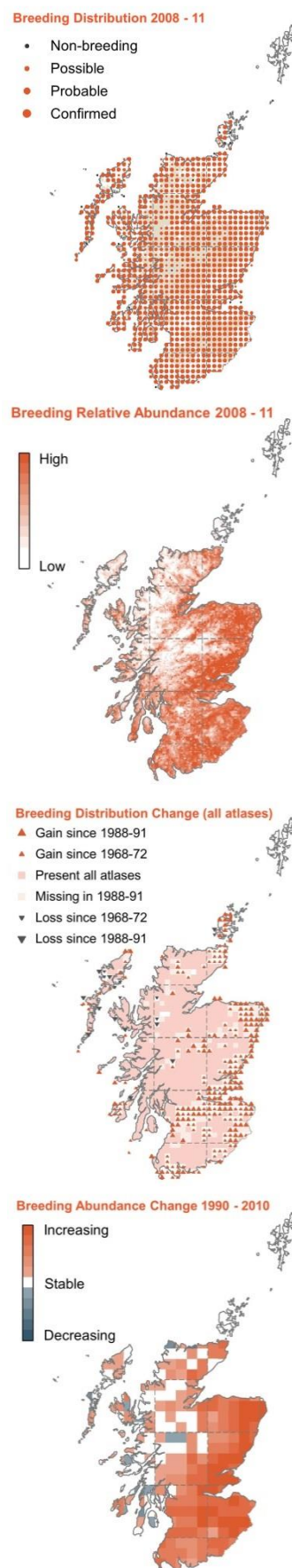


Fig. Current (A) distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Buzzard in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

and increased substantially in all the others (with the exception of Shetland, where the species still does not breed; [Appendix 11](#)). The largest range changes occurred in the Eastern Lowlands (net of 75 colonised 10-km squares), North East Coastal Plain (31 squares), West Central Belt (24 squares) and Border Hills (20 squares), with six more NHZs showing a net gain of 10 or more squares. Breeding abundance has increased in most areas since the late 1980s, most markedly in the Eastern Lowlands, North East Coastal Plain, Border Hills and North East Glens. The SRMS provides best available trends in breeding numbers from six study areas, well spread across Scotland and including both traditional buzzard strongholds and areas of recent population recovery; these currently span a restricted number of recent years and are highly variable from year to year, showing no consistent trends ([Roos et al. 2015](#)).

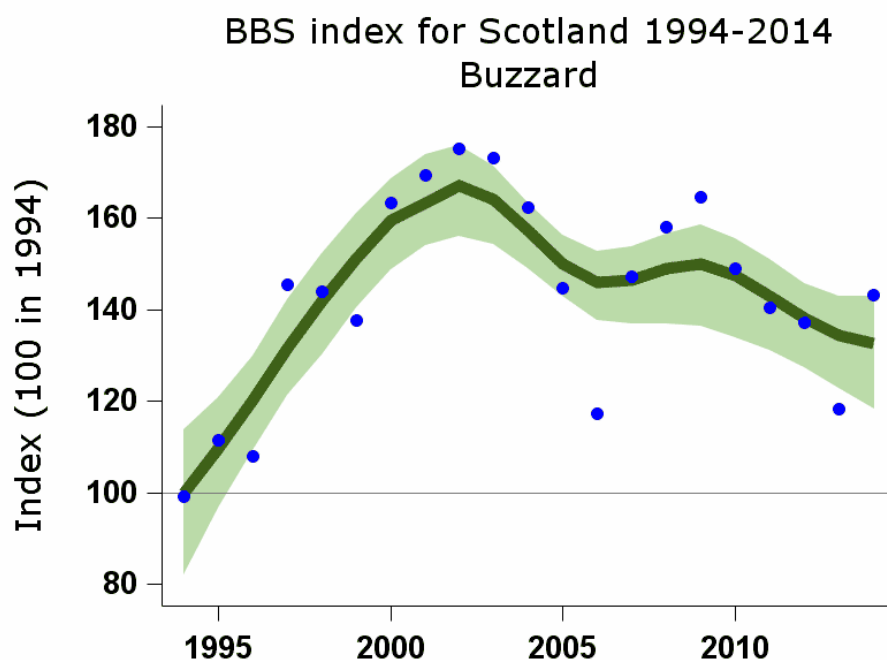


Fig. E Breeding Bird Survey trend for Common Buzzard 1994-2014.
(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Drivers of population change

In the early 1800s Buzzards were plentiful across most of Scotland but this changed after about 1830, when widespread control of numbers took place and by the end of the 1800s the species range was reduced to strongholds along parts of the west coast from Skye southwards to Ayrshire (Forrester et al. 2007). The reasons for the subsequent recovery of the population are not fully understood, although reduction in control is considered to have played an important role (Prytherch 2013). Rabbits form a key part of Buzzard diet, and their availability is known to influence both Buzzard breeding densities and breeding success (e.g. Graham et al. 1995). The widespread effects of myxomatosis on Rabbit populations in the 1950s (Parkin and Knox 2010) may have limited Buzzard populations at that time. However, Buzzards can have a very unspecialised diet (e.g. Rooney & Montgomery 2013 in Ireland), and this flexibility is likely to have aided population recovery, as well as the increase in breeding habitats (such as forestry plantations) in some areas (Balmer et al. 2013). In the uplands Buzzard abundance can be positively related to sheep stocking densities (Gibbons et al. 1995), and the changing availability of sheep and deer carrion may have influenced regional populations in Scotland. Buzzard abundance has been shown to be positively correlated

with an index of grouse moor density but there were several possible explanations for the relationship, including persecution, moorland management and relationships with food availability (Gibbons et al. 1995). Illegal killing of Buzzards is known to persist in Scotland (RSPB 2013) but the overall scale of the problem is difficult to establish. A recent study has shown that more than 75% of arable farms in Scotland use rodenticide poisons, and these are commonly found in the tissues of raptors, including Buzzards (Hughes et al. 2013). Whilst, for Buzzard, none of the deaths investigated in the study could be attributed directly to rodenticide poisoning, the authors conclude it likely that such mortality events are under-recorded, and the increased use of rodenticides to address Water Vole outbreaks has caused high levels of Buzzard mortality elsewhere (Coeurdassier et al. 2014). The possible influences of top predator densities (such as those of eagles and Goshawk) on the breeding Buzzard population in Scotland are not well understood but it is thought that Goshawk populations suppressed Buzzard populations in Germany (Chakarov and Krueger 2010) and Golden Eagles may suppress Buzzard densities on Mull (Fielding et al. 2003).

UK, EU and global status and trends

The recovery of the breeding population (range and abundance) in Scotland reflects wider recovery across almost the whole of England, and range expansion into much of the eastern half of Ireland since the late 1960s (Balmer *et al.* 2013; link to [Britain and Ireland atlas maps](#)). Range has increased by 123% in England and Wales since the late 1960s (a net gain of 901 10-km squares occupied; mostly in central and eastern England) and the large increases in abundance across much of southern and lowland Scotland are mirrored by large increases in central and southern England and northern Ireland in particular (refer to [mapstore maps](#)); breeding densities have also increased in some western strongholds of the species (Prytherch 2013). Breeding numbers, as surveyed via BBS, have increased very markedly and significantly in England since 1994 (+172%) and have been stable in Wales since that time, with the overall increase for the UK +75% (Harris *et al.* 2015; link to BBS website for graphs).

BOCC4 status = **Green**

Birds Directive status = n/a

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is available from the [SRMS annual reports](#) and [BTO BirdFacts](#). Provisional productivity information is available from six study areas: Cowal and Bute; Moray and Dornoch; Colonsay; Stirling and the Trossachs; Lothian; and the Uists; these are well spread across Scotland and include both traditional buzzard strongholds and areas of more recent population recovery. Breeding productivity parameters have generally been relatively stable in these study areas across recent years ([Roos et al. 2015](#)).

GOLDEN EAGLE

Aquila chrysaetos

Feeding habits

An apex predator and scavenger, regularly taking a range of young and adult birds, as well as mammalian prey.

Distribution and abundance in Scotland

Found breeding throughout the Scottish Highlands, north and west of the Highland Boundary Fault, and on most Hebridean islands (Fig. A). The species is currently most abundant in western Scotland, with high densities on Mull, in the southwest Highlands, Skye, parts of Wester Ross and the Outer Hebrides (most noticeably Lewis and north Harris, which had the highest densities recorded by the 2003 survey). Densities decrease at the eastern fringes of range and in parts of Argyll (Fig. B; see also Fig. 2 in Eaton *et al.* 2007). It is absent from the Northern Isles. In 2007-11 it was thought to breed in around 400 10-km squares.

Recent population trends in Scotland

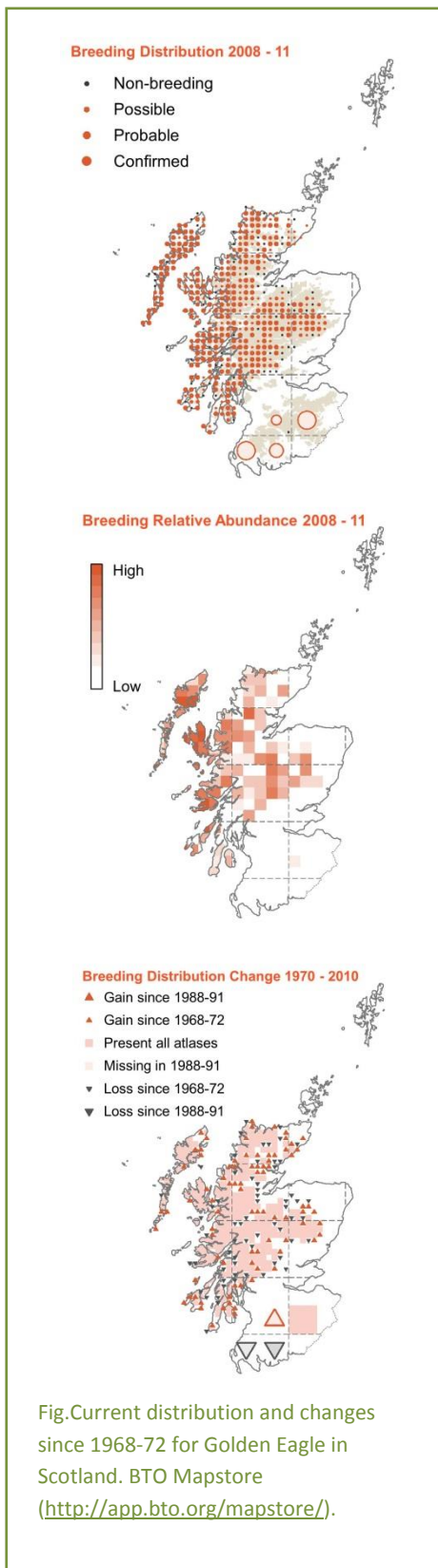
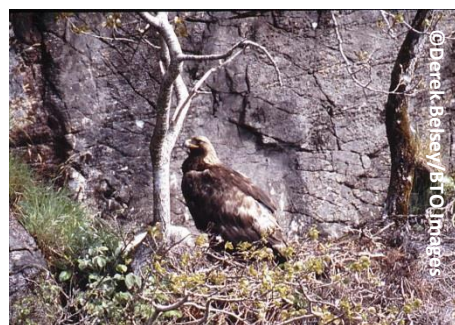
Population trends are available from three SCARRABS surveys : 1982/83 (Dennis *et al.* 1984) 424 pairs; 1992 (Green 1996) 422 pairs; 2003 (Eaton *et al.* 2007) 442 pairs. Using direct comparisons of coverage between the three surveys, the breeding population increased by 2.8% between 1992 and 2003 (and by 2.8% from 1982-83). The results of a fourth survey in 2015 are pending (Hayhow *et al.* in prep.). The Bird Atlas supports this relatively stability of the Scottish breeding population, with a change in range of only 4% between 1968-72 to 2007-11 (net gain of 14 10-km squares; see also Fig. C).

Geographical variation in Scottish trends

The apparent stability of the overall Scottish population masks considerable variation in breeding numbers at regional scale. Between 1992 and 2003 there were decreases in the eastern and south-central Highlands and increases on the Hebridean islands in particular (**Error! Reference source not found.**).

Drivers of population change

Extensive research and review of the factors influencing Scottish breeding Golden Eagles have established two major constraints on their populations: low food availability (associated with over-grazing and burning) in western areas; and illegal killing/disturbance (mainly associated with grouse moor management) in the central and eastern Highlands (Whitfield *et al.* 2003, 2004a & b, 2007, 2008;



Eaton *et al.* 2007). No evidence of competition with White-tailed Eagles has been found to date (Whitfield *et al.* 2013).

UK, EU and global status and trends

There are currently no breeding pairs in Britain outside of Scotland. A reintroduction project began in Donegal, Ireland in 2002, with two active nests and a number of other pairs and single birds by 2013 ([Golden Eagle Trust website](#)).

BOCC4 status = **Green**

Birds Directive status = Annex 1

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Recent demographic information is available in Eaton *et al.* (2007), Whitfield *et al.* (2008) and in the [SRMS annual reports](#).

Table 7. Numbers of pairs of Golden Eagle in eight areas of Scotland, and changes between years, as estimated by three national surveys in 1982/83, 1992 and 2003 (from Eaton *et al.* 2007).

Region	1982/83		1992		2003		Change (%)		
	Ranges checked	Pairs	Ranges checked	Pairs	Ranges checked	Pairs*	1982/83-1992	1992-2003	1982/83-2003
Eastern Highlands	57	30	51	36	90	29 (31)	+20	-19	-3
Northern moors and flows	42	22	40	16	43	20 (21)	-27	+25	-9
North-central Highlands	82	62	83	48	87	47 (48)	-23	-2	-24
South-central Highlands	59	43	58	36	65	31	-16	-17	-28
North-west Highlands	68	47	73	45	72	43 (45)	-4	-4	-9
West Highlands	95	75	97	79	98	77	+5	-3	+3
Southwest uplands and north	73	53	86	68	96	67 (69)	+28	-1	+26

England

Hebridean islands	122	92	122	94	147	120	+2	+28	+30
TOTAL	598	424	610	422	698	434 (442)	-0.5	2.8	2.4

* Due to greater coverage in the 2003 survey, comparisons with the previous surveys use a comparable sub-set of sites and pairs found. The full number found is given in brackets.



KESTREL

Falco tinnunculus

Feeding habits

Largely a predator of small mammals, but taking a range of other live prey, including small wild birds.

Distribution and abundance in Scotland

Kestrels are birds of open habitats and are widespread across most of Scotland, with the exception of uplands areas of the north and most of Lewis and Shetland (Fig. A). They are most abundant in the lowlands of south, central and eastern Scotland (Fig. B). Thought to breed in 789 10-km squares in 2007-11.

Recent population trends in Scotland

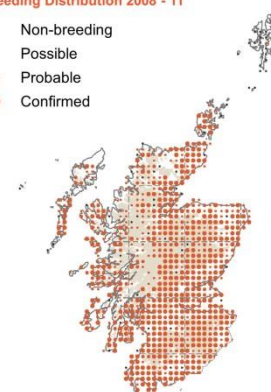
Since the late 1960s, range losses have occurred across parts of north and west Scotland, with fewer gains (e.g. in the Outer Hebrides; Fig. C); overall, the Scottish range has contracted by 11% ([Appendix](#)). Breeding abundance has decreased in most areas since the late 1980s, with the largest decreases in southern and eastern Scotland (Fig. D; an overall decrease of -32% since 1988-91). The national trend in kestrel breeding abundance (from BBS, Fig. E) showed a sustained and statistically significant decrease between 1994 and 2014. The overall change in abundance between 1995 and 2013 from BBS was -67%, the largest decrease shown by any Scottish species for which BBS produces trends (Harris et al. 2015). The BBS trend may not be fully representative of change in breeding numbers in Scotland however, as the sample of squares covered is heavily biased towards lowland areas ([Roos et al. 2015](#)).

Geographical variation in Scottish trends

Since the late 1960s, the overall decline in range (at 10-km resolution) of 11% has been most in evidence in Argyll West and Islands, North West Seaboard, North Caithness and Orkney, and Northern Highlands (these NHZs all losing 10 or more 10-km squares; [Appendix 11](#)).

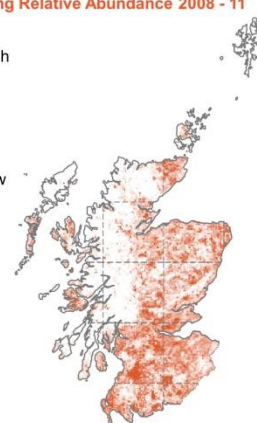
Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed



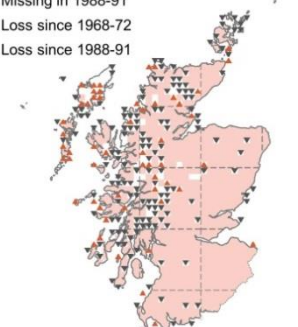
Breeding Relative Abundance 2008 - 11

High
Low



Breeding Distribution Change (all atlases) -11

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

Increasing
Stable
Decreasing

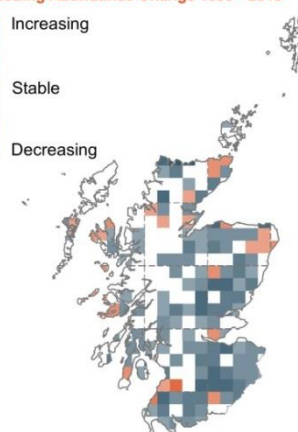


Fig. (A) Current distribution and (B) abundance, and changes since 1968-72 (C & D) for Kestrel in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

Breeding abundance has decreased in most areas since the late 1980s (Fig. D), most markedly in the North East Glens, Border Hills, Central Highlands, and Loch Lomond, the Trossachs & Breadalbane ([Appendix S3](#)). Data from a long-term study in southern Ayrshire demonstrate a substantial decline in breeding numbers since 1994 similar to that of the national BBS decline (Riddle in [Roos et al. 2015](#)).

Drivers of population change

Prior to the late 1990s, kestrels were known to be widespread as a breeding bird across Scotland but there was little quantitative data on population numbers (Village 1990; Forrester et al. 2007). Kestrels are known to favour unimproved grassland and similar habitats for hunting, and populations in Scotland are thought to have benefitted from the widespread afforestation that took place during the 1960s and 1970s (Forrester et al. 2007). Subsequently the scale of afforestation reduced and second rotation plantings were considered less favourable for the species; the Scottish population was considered fairly stable during the 1980s (Thom 1986) before the 1988-91 Bird Atlas demonstrated range contractions. A number of factors have been suggested as contributing to the declines since the late 1980s: agricultural intensification (e.g. loss of unimproved habitats) and reduction in small mammal populations (e.g. Shrubbs 2003); impacts of second-generation rodenticides (e.g. Cornulier et al. 2013); and competition or direct predation by recovering populations of other predatory birds, notably Goshawk (Petty et al. 2003; Forrester et al. 2007).

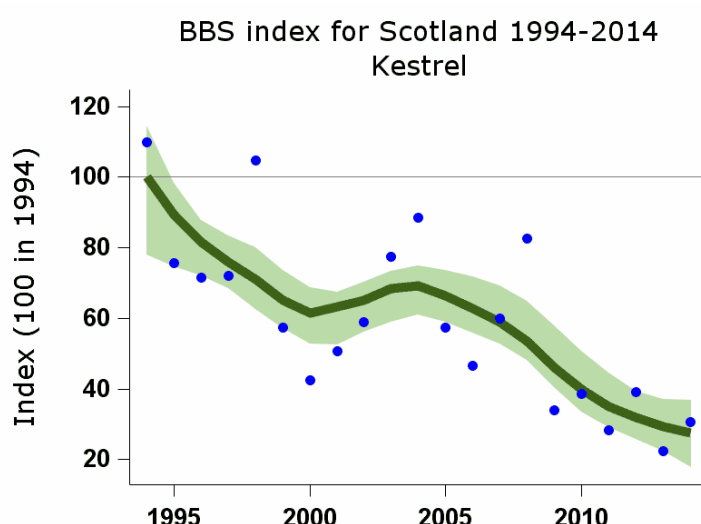


Fig. E Breeding Bird Survey trend for Kestrel 1994-2014.

(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

UK, EU and global status and trends

The loss of range seen in Scotland has also occurred in Wales and parts of Ireland (Balmer *et al.* 2013; link to [Britain and Ireland atlas maps](#)). The joint CBC/BBS trend in breeding abundance for England showed a substantial decrease between the mid-1970s and mid-1980s and further significant decline since 2002 (Baillie *et al.* 2014). Breeding numbers, as surveyed via BBS, have decreased significantly in England since 1994 (-27%; Harris *et al.* 2015). There has been widespread moderate decline across Europe since 1980 (PECBMS).

BOCC4 status = **Amber**

Birds Directive status = n/a

BirdLife EU status = LC
IUCN global status = LC

Demographic knowledge

Demographic information is available from the [SRMS annual reports](#) and [BTO BirdFacts](#). Productivity information is available from a long-term study in south Ayrshire; this shows considerable variation between years but no systematic trend since 2003 (Riddle in [Roos *et al.* 2015](#)).



MERLIN

Falco columbarius

Feeding habits

A specialist predator of small birds.

Distribution and abundance in Scotland

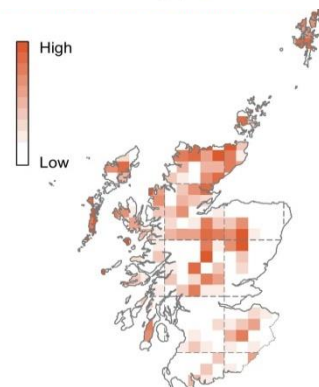
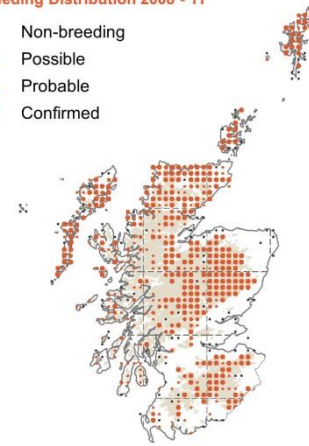
Current distribution reflects the species' preference for heather-dominated moorland, the range including parts of the Southern Uplands, the central and north-east Highlands, the north of Scotland, Northern Isles and Western Isles (Fig. A). Generally most abundant in the north and east of the Scottish range (Fig. B). Thought to breed in 449 10-km squares in 2007-11.

Recent population trends in Scotland

The British population reached a low point in the 1960s, largely as a result of the use of organochlorine agricultural pesticides (Newton 1986). The Scottish range has recovered by 25% since the late 1960s, with a net colonisation of 90 10-km squares (Fig. C) and consecutive Bird Atlas surveys showing range expansion up to the late 1980s but overall stability since. Scottish population estimates are also available from three national surveys : a partial survey in 1983/84 (Bibby & Nattrass 1986); 1993/94 (Rebecca & Bainbridge 1998) 785 (95% confidence limits 602–994) breeding pairs; 2008 (Ewing et al. 2011) 733 (512–979) breeding pairs and a -7% (non-significant) change from 1993/94. A subsequent review of Merlin numbers in Scotland (Haworth & Fielding 2011) suggested that the population estimated by the 2008 survey was too high. Disagreement hinged principally on extrapolation from the stratified element of the survey, the numbers in intensively studied areas being relatively undisputed. A further estimate of population size, using breeding numbers found in well-studied areas of Scotland and geographical variation in relative abundance from the most recent Bird Atlas produced a revised estimate of 433 pairs (95% confidence limits 283-594; Wilson et al. 2015). The overall change in relative abundance in Scotland between 1988-91 and 2007-

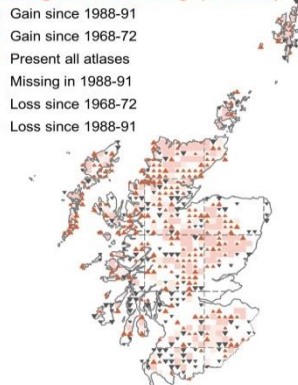
Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

- Increasing
- Stable
- Decreasing

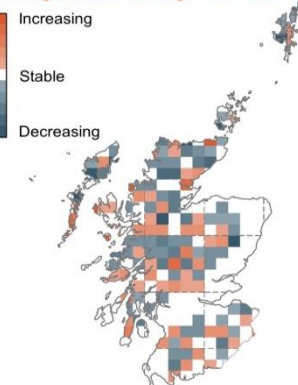


Fig. (A) Current distribution and (B) abundance, and changes since 1968-72 (C & D) for Merlin in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

11 from the Bird Atlas survey was -19%.

Geographical variation in Scottish trends

Comparisons for three areas that were well covered during both the 1983/84 and 1993/94 surveys suggested population increase (recovery) in Orkney and Shetland and population stability in north-east Scotland (Rebecca & Bainbridge 1998). Between the 1993/94 and 2008 surveys, the population on Orkney increased slightly whilst that in north-east Scotland declined by 27% (Ewing *et al.* 2011).

Since the late 1960s, the pattern of range change has varied across Scotland (Fig. C). The NHZs with the largest positive range changes were the Peatlands of Caithness & Sutherland (net of 25 colonised 10-km squares), Coll, Tiree & the Western Isles (18 squares) and North West Seaboard (14 squares), with three other NHZs showing a net gain in occupancy of 10 or more squares ([Appendix S3](#)). Conversely net losses have also occurred, most markedly from the Western Southern Uplands & Inner Solway (net loss of 16 10-km squares) but also from four other NHZs. Relative abundance changes since the late 1980s have also been variable spatially (Fig. D).

Drivers of population change

The recovery of the British Merlin population up to the 1993/94 survey probably occurred as a result of lack of persecution, recovery from the adverse effects of agricultural pesticides and the increased use of forest edge as a nesting habitat (Rebecca & Bainbridge 1998; Rebecca 2011; Newton 2013; Newton *et al.* 1982, 1999). The declines in some areas of Scotland since the early 1990s may be due to a combination of adverse upland management practices, such as muirburn (e.g. in north-east Scotland), reductions in prey populations (of small moorland songbirds and more generally of small songbirds wintering on farmland), changes in forest structure (e.g. in south-west Scotland) and possibly climate change (Ewing *et al.* 2011) but none of these drivers is particularly well understood for Merlin. Additionally, frequently nesting on the ground, Merlins can be susceptible to ground predators, as well as predation or intra-guild intimidation from other raptors (Dickson 2000, 2006; Rae 2010; Weir 2013). Any population impacts of such predation are poorly understood however.

UK, EU and global status and trends

An overall reduction of 10% in the breeding range in England and Wales since the 1960s (net loss of 25 10-km squares) is counter to the net increase in Scotland, as is the 40% reduction in range in Ireland over the same period (net loss of 25 squares; Balmer *et al.* 2013; link to [Britain and Ireland atlas maps](#)). In contrast to the overall picture of stability or increase across England and Wales between the 1983/84 and 1993/94 surveys (Rebecca & Bainbridge 1998), the 2008 survey showed decreases in breeding numbers of -38% to -83% in well-studied areas of Wales and England (Ewing *et al.* 2011). Numbers and trends in Ireland are poorly known (Lusby *et al.* 2011).

BOCC4 status = **Red**

Birds Directive status = Annex 1

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Recent demographic information is available in the [SRMS annual reports](#) and [BTO BirdFacts](#).

PEREGRINE

Falco peregrinus

Feeding habits

A specialist predator of small- to medium-sized birds.

Distribution and abundance in Scotland

Widespread as a breeding species across the whole of Scotland (Fig. A). Traditionally a bird of upland and coastal areas with suitable cliffs for nesting, the species now breeds across most lowland areas, using quarries and tall man-made structures as nest sites. It is most abundant in the south of Scotland and the central and eastern Highlands, and least abundant in the north and west (Fig. B), and only recently re-established as a breeding species on Shetland. Thought to breed in 575 10-km squares in 2007-11.

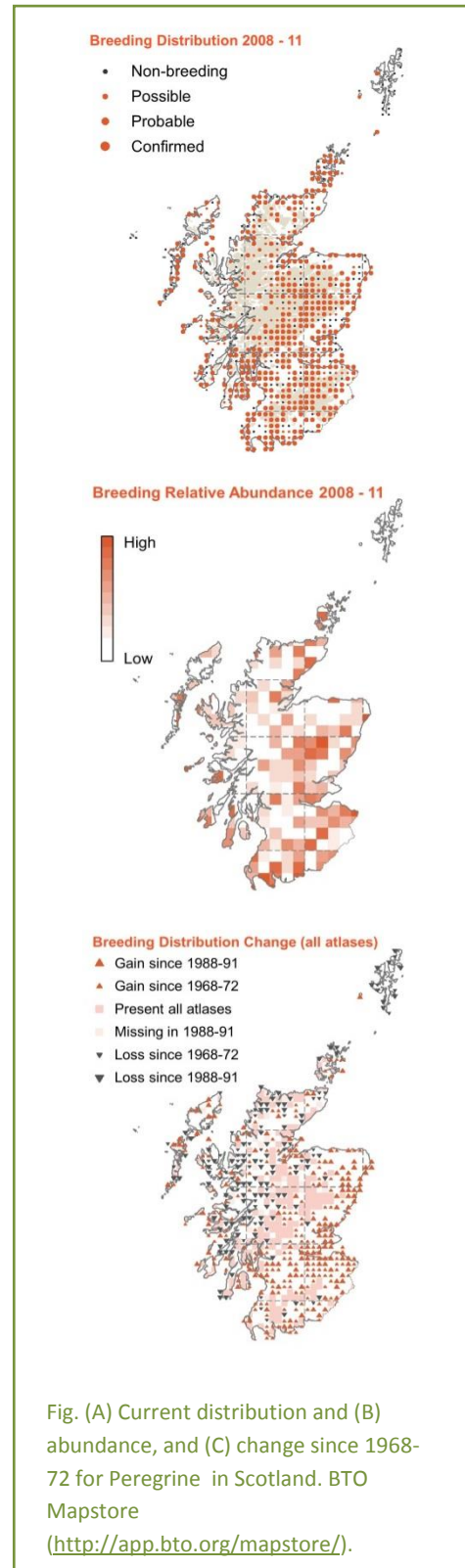
Recent population trends in Scotland

The decline in the number of breeding Peregrines in Scotland as a result of secondary organochlorine pesticide poisoning began later than in England and Wales and the population was probably at its lowest point in the early 1970s (Ratcliffe 1993; Crick & Ratcliffe 1995; Ratcliffe 2003).

The Scottish range has recovered by 40% since the late 1960s, with a net colonisation of 164 10-km squares (Fig. C) and consecutive Bird Atlas surveys showing range expansion up to the late 1980s (+46%) but suggestion of slight contraction (-4%) since. Scottish trends since the 1960s are also available from six national surveys in: 1961/62 (Ratcliffe 1963); 1971 (Ratcliffe 1972); 1981 (Ratcliffe 1984); 1991 (Crick & Ratcliffe 1995); 2002 (Banks et al. 2010); and 2014 (Wilson et al. in prep.). Peregrine breeding populations have traditionally been compared to an estimated baseline population in 1930-39, a period before the marked declines attributable to organochlorine pesticides and more local factors took place (515 pairs; **Error! Reference source not found.**). The estimated total number of pairs in Scotland in 1962 was 388, 366 pairs in 1971 and had increased to 442 pairs by 1981 (Ratcliffe 1984, 1993). The recovery continued to 1991, 626 pairs (122% of the 1930-39 baseline) but by 2002, this had dropped to 571 or 111% of the 1930-39 number (**Error! Reference source not found.**; Banks et al. 2010). Some of these figures may differ slightly from those reported in earlier publications because the numbers of 'Ratcliffe pairs' that are used for the direct comparisons between surveys need to be adjusted slightly each time new survey



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information is produced.

The estimated breeding population from the 2014 survey currently stands at 469–487 pairs (suggesting a further drop of 15–18% since 2002; Wilson *et al.* in prep.). The overall change in relative abundance in Scotland between 1988–91 and 2007–11 from the Bird Atlas survey was –36%.

Geographical variation in Scottish trends

Trends in breeding numbers were showing regional variation by the time of the 1981 survey (Ratcliffe 1993). The 1991 survey indicated increases over much of Scotland (but at variable rates, lower in north and western inland areas and in the south west compared to the rest of the country), and in northern and western coastal areas a decline had occurred between 1981 and 1991 (Crick & Ratcliffe 1995). By 2002 the differences in population trends in Scotland were even more marked (**Error! Reference source not found.**): marked increases only occurred between 1991 and 2002 in southern coastal areas (+55%) and coastal areas of Tayside and north-east Scotland (+71%), the population inland in southern Scotland increased by 18% and in other areas (which held more than 60% of the Scottish population in 2002) declines ranged from –16 to –22%, hence the overall decline of 9% in the breeding population between 1991 and 2002 (**Error! Reference source not found.**). Although the number of breeding pairs of Peregrines declined in most regions between 2002 and 2014, the southern central regions of South Strathclyde and Lothian & Borders experienced increases. These trends are indicative of substantial changes in population distribution in recent decades, which are reflected in the results of the consecutive Bird Atlas surveys (Fig. C). Peregrines have more than doubled their range in six NHZs since the late 1960s, with the largest positive range changes in lowland areas: the Eastern Lowlands (net of 68 colonised 10-km squares) and West Central Belt (28 squares). In contrast, range contracted in seven NHZs, all predominantly upland, with the largest losses from the North West Seaboard (net loss of 12 10-km squares) and East Lochaber (11 squares; Table 8). Conversely net losses have also occurred, most markedly from the Western Southern Uplands & Inner Solway (net loss of 16 10-km squares) but also from four other NHZs. Breeding Peregrines were lost from Shetland completely in 1999 (Pennington *et al.* 2004) but have recolonized in small numbers since, with one successful breeding attempt recorded during the 2014 survey (Wilson *et al.* in prep.).

Drivers of population change

The British population reached a low point in the 1960s, largely as a result of secondary poisoning from organochlorine agricultural pesticides and persecution during the Second World War (Ratcliffe 1993; Crick & Ratcliffe 1995; Ratcliffe 2003). The reduction of both of these threats has most likely allowed the recovery of the population since that time (Ratcliffe 1993), although persecution has not been eliminated completely (Banks *et al.* 2010; Amar *et al.* 2012; Hardey *et al.* 2003). Expansion into new breeding areas, including quarries and other human-made sites, is a major feature of the post-1981 increase (Crick & Ratcliffe 1995; Banks *et al.* 2010), demonstrating the flexibility of the species and perhaps the relative abundance of food resources in the lowlands and urban areas. Suggested reasons for declines in upland areas of Scotland in the most recent decades are continuing persecution in some areas managed for red grouse shooting (e.g. north-east Scotland; North East Scotland Raptor Study Group 2015) and reduced prey availability, both of wild bird prey (due to habitat degradation; Humphreys *et al.* 2007; Banks *et al.* 2010) and racing pigeons (due to changes in racing routes; Shawyer *et al.* 2000; Hardey *et al.* 2003; Humphreys *et al.* 2007). Marine pollution and defensive nesting Fulmars may contributed to losses in coastal areas (Newton *et al.* 1989; Ellis & Okill 1993) and many other factors potentially contributing to changes in the Scottish population have been considered (Humphreys *et al.* 2007).

UK, EU and global status and trends

In contrast to the modest recovery of range of the Scottish population since the late 1960s and recent regional declines, the combined range in England and Wales expanded by 747% between 1968–72 and 2007–11 (a net gain of 777 10-km squares; Balmer *et al.* 2013; link to [Britain and Ireland](#)

[atlas maps](#)). The range in Ireland also expanded by 276% during the same time period, with the population at an all-time high, and most recent increases (since the early 1990s) at inland quarries and human-made sites (Madden *et al.* 2009). The most recent national survey results show continued growth in breeding numbers in England (+34% since 2002 but a lower rate of increase than in previous decades; **Error! Reference source not found.**), and continued modest growth in Northern Ireland (+17%), whilst the Welsh population now appears to be showing a modest decline, of similar magnitude to that in Scotland.

BOCC4 status = **Green**

Birds Directive status = Annex 1

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Recent demographic information is available in the [SRMS annual reports](#) and [BTO BirdFacts](#).

Provisional trends in breeding productivity parameters from up to eight NHZs (or part NHZs) have shown no systematic change since 2003 ([Roos *et al.* 2015](#)).

Table 8. Numbers of ‘Ratcliffe pairs’* of Peregrine in Scotland compared with first estimates in 1930-39 (from Banks et al. 2010 & Wilson et al. in prep.) and other parts of the UK.

Region 1991	Region(s) 2002	1930- 1939	1991	Change 1930- 1939 to 1991	2002	Change 1991 to 2002	Change 1930- 1939 to 2002	2014	Change 2002 to 2014
South Scotland (coastal)	South Strathclyde (coastal)	26	33	+27%	51	+55%	+96%		
	Dumfries & Galloway (coastal)								
	Lothian & Borders (coastal)								
South Scotland (inland)	South Strathclyde (inland)	30	93	+210%	110	+18%	+267%		
	Dumfries & Galloway (inland)								
	Lothian & Borders (inland)								
South & east Highlands west (coastal)	Argyll (coastal)	36	49	+36%	41	-16%	+14%		
South and east Highlands fringe (inland)	Tayside (inland)	252	341	+35%	267	-22%	+6%		
	Argyll (inland)								
South & east Highlands centre (inland)	Central (all)								
North & west Highlands (inland)	Highlands (inland)								
	North-east Scotland (inland)								
South & east	Tayside	14	14	0%	24	+71%	+71%		

Highlands east (coastal)	(coastal)							
	North-east Scotland (coastal)							
North & west Highlands west (coastal)	Shetland	157	96	-39%	78	-19%	-50%	
	Orkney							
North & west Highlands east (coastal)	Western Isles							
	Highlands (coastal)							
Scotland: coast		233	192	-18%	194	+1%	-17%	
Scotland: inland		282	434	+54%	377	-13%	+34%	
SCOTLAND TOTAL		515	626	+22%	571	-9%	+11%	469-487 -15 to -18%
ENGLAND TOTAL		167	285	+71%	470	+65%	+181%	628 +34%
WALES TOTAL		127	258	+103%	283	+10%	+123%	249 -12%
NORTHERN IRELAND TOTAL		54	96	+78%	82	-15%	+52%	96 +17%

* The number of notional 'Ratcliffe pairs' is the number of pairs observed plus half the numbers of single birds found occupying territories (and assumes that half of single birds observed actually have a mate). This standard unit was introduced by Derek Ratcliffe and has been adopted for comparative survey reporting purposes for the species since.

TAWNY OWL

Strix aluco

Feeding habits

A specialist nocturnal predator of small mammals, but taking a range of other live prey, including wild birds up to the size of a Woodpigeon, during the late spring and summer when small mammals are harder to catch. Thought to eat more birds in urban habitats.

Distribution and abundance in Scotland

Previously considered a species of broad-leaved woodland, Tawny Owls now occur in almost all habitats. They are present breeding throughout Scotland, with the exception of the high uplands of the central and north-west Highlands, the Northern Isles, Outer Hebrides and some of the smaller Inner Hebridean islands (Fig. A). They are most abundant in lowland deciduous woodlands, in south, central and eastern Scotland and parts of Argyll (Fig. B). Thought to breed in 615 10-km squares in 2007-11.

Recent population trends in Scotland

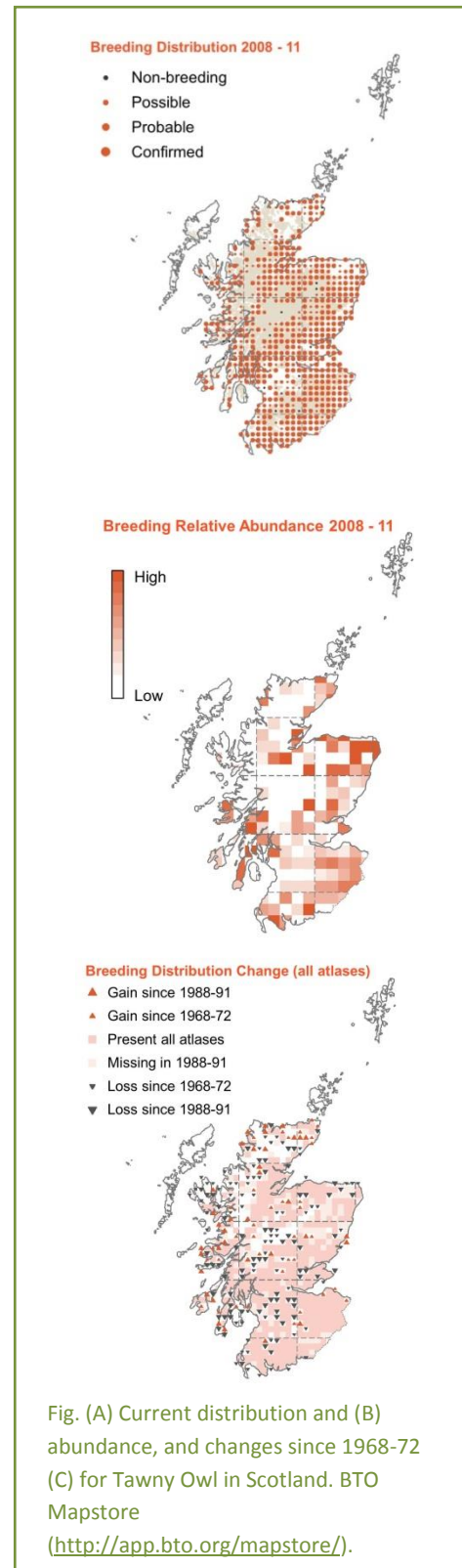
Numbers were thought to decline during the 18th, 19th and early 20th Centuries due to deforestation and killing on game estates but then began to recover, particularly between the two World Wars (Forrester et al. 2007). Since the late 1960s the Scottish range has shown a net decrease of -10% (a net loss of 68 10-km squares; Fig. C). Standard atlas survey methods are not ideal for this species, however, due to its low detectability during the main atlas recording period and some of the losses of range may reflect lack of detection in areas of low owl density (Balmer et al. 2013). Some of the gains in the north and west of Scotland are thought to be real, however, as a result of maturing forestry creating suitable habitat for the species. No overall Scottish breeding abundance trend is available for this species.

Geographical variation in Scottish trends

Since the late 1960s, range losses have been well spread across the country (Fig. C), with only two NHZs showing losses of 10 or more 10-km squares (West Central Belt and Western Southern Uplands & Inner Solway; [Appendix 11](#)).

Drivers of population change

Recovery of the population in the 20th Century, particularly between the two World Wars, was probably a result of a reduction in keeping on game estates. Organochlorine



agricultural pesticides were not thought to have a major negative impact on the species in the 1950s/1960s because of the low proportion of birds (the major source of contamination) in the diet (Forrester et al. 2007). Local range changes in Scotland may have been a result of changes in availability of mature woodland (maturing of forestry; Balmer et al. 2013). No link to the adverse effects of secondary rodenticide poisoning has been found to date (Walker et al. 2008).

UK, EU and global status and trends

The small loss of range in Scotland is also suggested in England and Wales (range change of -4%, net loss 65 10-km squares since the late 1960s, also supported by some local atlas studies; Balmer et al. 2013; link to [Britain and Ireland atlas maps](#)). Tawny Owl is not a regular breeding bird in Ireland. The joint CBC/BBS trend for UK/England shows no overall significant trend for the whole period since the late 1960s but a significant downward trend (-31%) in the last 25 years ([Baillie et al. 2014](#)). Breeding numbers, as surveyed via BBS, have shown a significant -20% decline at UK scale since 1995 ([Harris et al. 2015](#)).

BOCC4 status = **Amber**

Birds Directive status = n/a

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is available from the [SRMS annual reports](#) and [BTO BirdFacts](#).



SHORT-EARED OWL

Asio flammeus

Feeding habits

In Britain, a major prey item is the Short-tailed Field vole, though other small mammals can be important, notably on islands where voles are absent or where alternative prey is available, for example, Common Voles in Orkney (Glue 1977). Birds, especially young, can be taken as prey but these appear to be unimportant in Britain.

Distribution and abundance in Scotland

Most breeding Short-eared owls are associated with moorland and the highest densities are reported from rough grasslands adjacent to, or intermixed with, heather moors (marginal hill ground or 'white moor') where a diversity of sward structures could be important (Calladine & Morrison 2013). Young conifer plantations can also be important habitats (Shaw 1995), though second and later rotation plantings are perceived to be less used than initial plantings. Lowland rough grassland, marshes and coastal sand dunes are also used for breeding though their use of such areas can be erratic, except on some of the western islands and Orkney. Their distribution is limited by the availability of those habitats and of its preferred prey, voles (Fig. A). In the Northern Isles they occur in Orkney (with voles) but generally do not breed in Shetland (no voles). Similarly in the Western Isles, they are present on Uist (voles) but generally absent from Lewis and Harris (no voles). In mainland Scotland, the highest densities are associated with managed grouse moors along the eastern periphery of the Highlands and in Caithness, but generally not where heather is managed to the exclusion of rough grassland. Relatively high breeding densities are also found in Orkney and Uist (Fig. B).

Recent population trends in Scotland

The number of 10-km squares in which breeding Short-eared Owls were recorded in Scotland decreased by 50% between 1970 and 2010, most of that (40%) occurring between 1990 and 2010. Losses have occurred throughout the Scottish range (Fig. C). The abundance of breeding

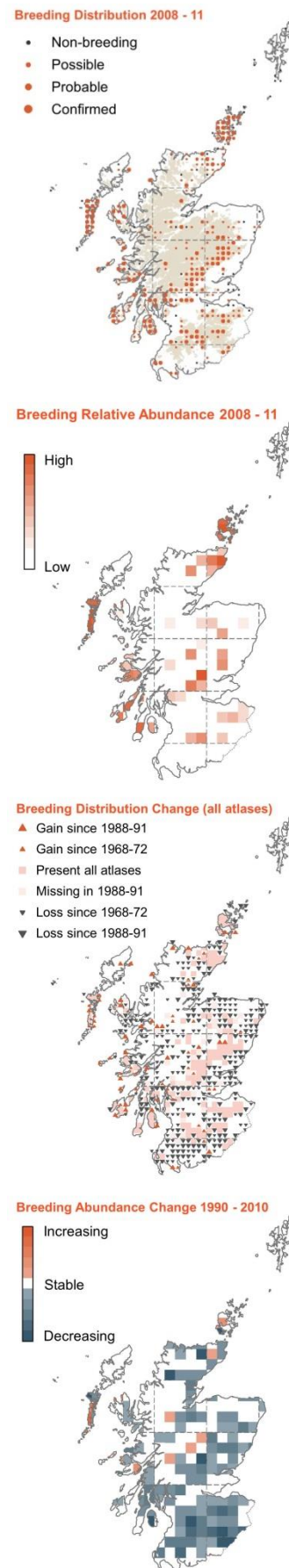


Fig. Current distribution and changes since 1968-72 for Short-eared Owl in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

Short-eared owls has also decreased throughout most of the species' remaining range (Fig. D). The status and trends of Short-eared Owls are amongst the least known of any predatory bird in Scotland with any surveys likely biased towards the detection of those that have successfully hatched young (Calladine *et al.* 2010). However, as the *Atlas* surveys each cover multiple years, the generality of the apparent declines and range contraction are likely to be representative.

Drivers of population change

Short-eared Owls can be nomadic and irruptive with individuals capable of shifting breeding areas even between countries within Europe in response to fluctuations in the abundance of their small mammal prey. However, a number of areas in Scotland appear to support constant and even relatively high breeding densities over many years. The degree and nature of connectivity between birds that breed in different parts of Scotland, Britain and elsewhere in Europe remains unclear, however sometimes high densities and breeding outside of their regular range can occur in years following irruptive movements of (presumably) Scandinavian birds (Calladine *et al.* 2012). Losses in some areas have been associated with the maturation of forestry plantations. The remaining strongholds tend to be either islands or associated with managed grouse moors, both situations where the densities and assemblage of mammalian predators can be low, either because of natural insularity or through managed control. A negative influence of ground predators appears likely.

British, Irish and European Trends

Declines in the range and abundance of breeding Short-eared Owls have also occurred through the rest of Britain. Contraction of occupied range (as measured by presence in 10-km squares) of 48% in Britain was reported between 1970 and 2010 and there was a decline in relative abundance of -0.63 (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013). Small numbers breed, perhaps sporadically, in Ireland and could be associated with introduced populations of voles (voles are not native in Ireland). Short-eared Owls have been subject to population declines and range contractions across a number of range states in Europe (Tucker & Heath 1994). However, its current European Red List Status is as of 'Least Concern' in response to its extensive range across the continent and evidence of increases in some range states (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Amber**

Birds Directive status = Annex 1

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is limited (see [SRMS annual reports](#) and [BTO BirdFacts](#)).

4.3 Review of population trends for corvid predators of wild birds



MAGPIE

Pica pica

Feeding habits

An opportunistic species, for which the eggs and young of wild birds form a substantial part of the diet.

Distribution and abundance in Scotland

Present across most of southern Scotland, the Central Belt, the north-east lowlands and around the Moray Firth but largely absent from the Highlands, west coast and islands (Fig. A). Thought to breed in 376 10-km squares in 2007-11. Most abundant across the Central Belt and much more scarce elsewhere (Fig. B).

Recent population trends in Scotland

Prior to World War II, Magpies were scarce in Scotland following decades of legal control by gamekeepers, farmers and gardeners (Forrester et al. 2007). Subsequently the population started to recover but was still confined to the central lowlands by the late 1960s. Since that time further recovery and consolidation of its range has occurred in southern, central and eastern Scotland, as far north as Moray and Nairn, with most of that expansion occurring since the mid 1990s (Forrester et al. 2007; Fig. C). Since the late 1960s the Scottish range has expanded by 36%, with a net colonisation of 100 10-km squares. Breeding abundance has also increased in most of the Scottish range since the early 1990s (Fig. D), overall by 60% from Bird Atlas surveys. The national trend in magpie breeding abundance between 1995 and 2013 (from BBS, Fig. E) shows an overall change of +22% (lower and upper confidence limits -13 to +87%, so not significant over the whole period; [Harris et al. 2015](http://harris.et.al.2015)).

Geographical variation in Scottish trends

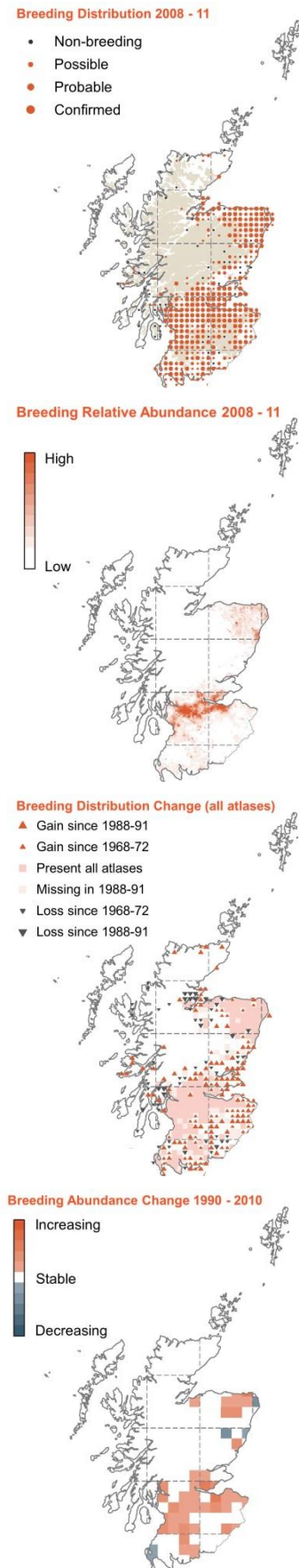


Fig. (A) Current distribution and (B) abundance and (C & D) changes (1968-72 to 2007-11), for Magpie in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

Most of the range expansion since the late 1960s has occurred in three NHZs ([Appendix 11](#)): the Eastern Lowlands (net of 50 colonised 10-km squares); Western Southern Uplands & Inner Solway (24 squares); and Border Hills (14 squares). In all other NHZs in which the species occurs range has altered by less than 5 10-km squares. Breeding abundance has increased in most areas since the late 1980s (Fig. D), most markedly in the West Central Belt, Eastern Lowlands, Western Southern Uplands & Inner Solway and North East Coastal Plain ([Appendix S3](#)).

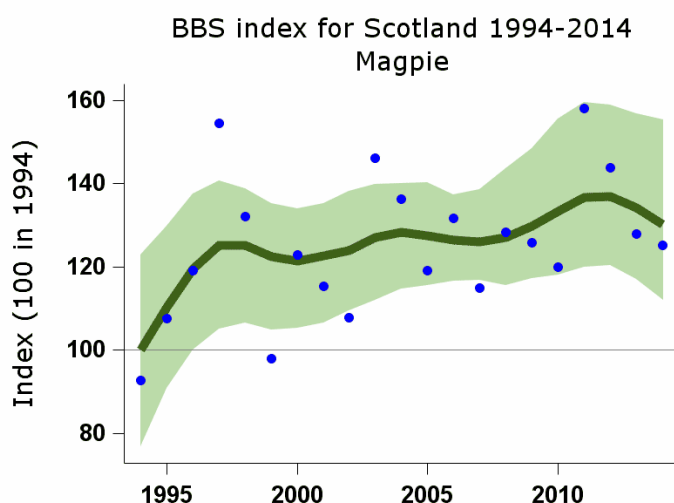


Fig. E Breeding Bird Survey trend for Magpie 1994-2014.

(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Drivers of population change

The overall recovery of range and increase in abundance since the late 1960s is largely attributable to a reduction in control by humans (Forrester et al. 2007). It is thought that during the early 1900s when control was much more widespread, Magpies persisted close to human settlements where less control generally took place (Tatner 1982), and from these refuges the population of this opportunistic species expanded into the surrounding countryside when control was relaxed. An overall improvement in productivity (number of fledglings produced per breeding attempt) is thought to have made a major contribution to population expansion (at UK scale; Baillie et al. 2014). In some areas the increased availability of nest sites through afforestation may have assisted colonisation (Balmer et al. 2013). In recent decades, corvid populations may have benefitted from an increased food supply made available by the pheasant shooting industry (in the form of seed hoppers and road kills) but research is lacking.

UK, EU and global status and trends

The recovery of the breeding population (range and abundance) in Scotland reflects wider recovery across the rest of Britain. Range expansion in England and Wales has only been modest since the late 1960s (+2% and net gain of 34 10-km squares; Balme et al. 2013; link to [Britain and Ireland atlas maps](#)). However, abundance change in England as measured by the CBC/BBS surveys was very rapid during the 1970s and 1980s (change 1967-2012 of +107%, 95% confidence limits 68-165%; [Baillie et al. 2014](#)) but has stabilised subsequently (BBS trend stable since 1995; [Harris et al. 2015](#)). BBS also shows a stable breeding population in Northern Ireland but a significant decline (of -16%) in Wales

since 1995 ([Harris *et al.* 2015](#)). There has been widespread moderate decline across Europe since 1980 ([PECBMS](#)).

BOCC4 status = **Green**

Birds Directive status = Annex 2.2

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is available from [Baillie *et al.* 2014](#), [BTO BirdFacts](#) and Forrester *et al.* 2007.



JAY

Garrulus glandarius

Feeding habits

An opportunistic species, for which the eggs and young of wild birds form part of a mixed diet.

Distribution and abundance in Scotland

This largely woodland bird is now present across most of southern Scotland, the Central Belt and southern Highlands, much of the north-east lowlands, Argyll and through the Great Glen (Fig. A); it is absent from the high areas of the central Highlands, most of the north and west mainland, the Northern Isles, Outer Hebrides and most of the Inner Hebrides. It was thought to breed in 433 10-km squares in 2007-11. Abundance is strongly related to the presence of tracts of woodland (both broad-leaved and coniferous), being greatest in the southern highlands of Perth and Kinross, Angus and Dundee, around Loch Lomond and in central Argyll (Fig. B).

Recent population trends in Scotland

In recent centuries, this species was subject to widespread legal control in Scotland, particularly to protect gamebird interests (Thom 1986). Since the late 1960s the Scottish range has expanded greatly (by 118%), with a net colonisation of 234 10-km squares, much of this since the late 1980s and most markedly in the Borders, north-east Scotland and through the Great Glen (Fig. C). Breeding abundance has also increased markedly in much of the Scottish range since the early 1990s (Fig. D), overall by 121%.

Geographical variation in Scottish trends

The NHZs showing the greatest range expansion since the late 1960s ([Appendix 11](#)) are: the Eastern Lowlands (net of 46 colonised 10-km squares); Border Hills (23 squares), Northern Highlands (22 squares) and West Central Belt (20 squares). Range increased by 10 or more 10-km squares in a further eight NHZs. In all other NHZs in which the species occurs range altered by 6 10-km squares or less. Breeding abundance has increased in most areas since the late 1980s (Fig. D), most markedly in the Western Southern Uplands &

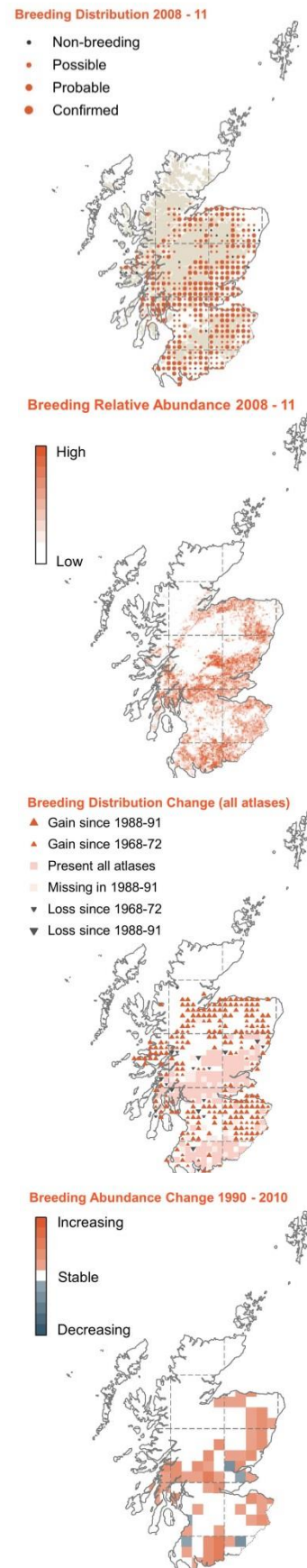


Fig. (A) Current distribution and (b) abundance, and (C & D) changes (1968-72 to 2007-11) for Jay in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

Inner Solway, Eastern Lowlands, North East Glens and Loch Lomond, The Trossachs & Breadalbane ([Appendix S3](#)).

Drivers of population change

The overall recovery of range and increase in abundance since the late 1960s is largely attributable to a reduction in control by humans and increases in forestry (where predator control tends to be minimal) in some areas (Forrester et al. 2007).

UK, EU and global status and trends

The range in England and Wales has changed little since the late 1960s (+1% and net gain of 13 10-km squares; Balmer et al. 2013; link to [Britain and Ireland atlas maps](#)). Abundance change at UK scale as measured by the CBC/BBS surveys showed stability until the late 1980s, after which the population began to decline until the mid 1990s (so that the long-term trend from the 1960s was stable overall; Baillie et al. 2014). Recent trends from BBS show a modest but significant increase since the mid 1990s in England (+12%) and a greater increase (+41%) in Wales. No BBS trend is available for Scotland currently. There has been widespread moderate increase across Europe since 1980 ([PECBMS](#)).

BOCC4 status = **Green**

Birds Directive status = Annex 2.2

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is available from the [Baillie et al. 2014](#) and [BTO BirdFacts](#).



JACKDAW

Corvus monedula

Feeding habits

An opportunistic species, for which the eggs and young of wild birds form part of a mixed diet.

Distribution and abundance in Scotland

Widespread as a breeding species across much of Scotland but absent from large parts of north-west Scotland and scarce on many of the Scottish islands (Fig. A). Thought to breed in 634 10-km squares in 2007-11. Feeding mainly on farmland, it is most abundant in the lowland parts of the range (Fig. B).

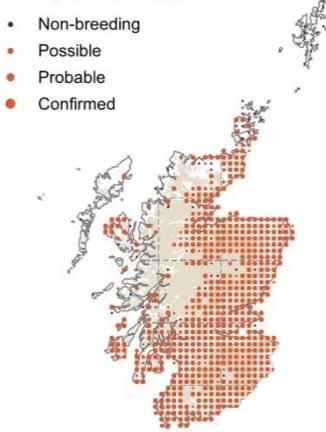
Recent population trends in Scotland

It is thought that Jackdaws became much more widespread in Britain in the second half of the 19th Century and into the 20th Century (Forrester et al. 2007). There has been little change in the Scottish breeding range since the late 1960s, with a few gains and losses, largely in marginal upland areas (Fig. C; small net change of -11% or loss of 77 10-km squares). The losses have occurred from areas with low densities and so could be an artefact of changed detection rates but they might also be a consequence of reduction in the extent of suitable farmland on which to feed, through changes in grazing or afforestation (Balmer et al. 2013). In contrast, breeding abundance has shown some increase since the early 1990s (Fig. D; 11% increase from Bird Atlas surveys). The national trend in Jackdaw breeding abundance between 1995 and 2013 (from BBS, Fig. E) shows an overall change of +20% (lower and upper confidence limits -7 to +64%, so not significant over the whole period; [Harris et al. 2015](#)).

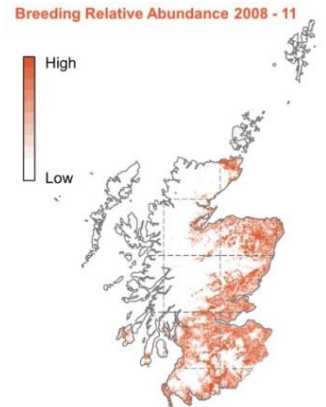
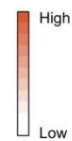
Geographical variation in Scottish trends

Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed

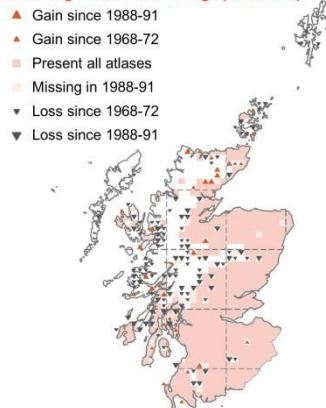


Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

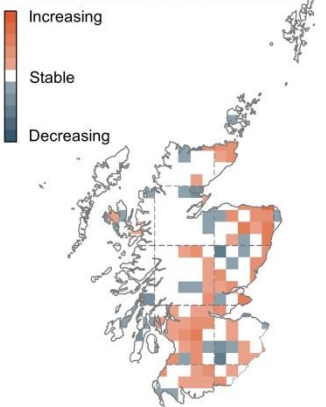
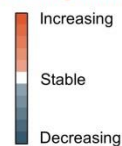


Fig. (A) Current distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Jackdaw in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

Breeding range has decreased by five or more 10-km squares in seven NHZs (Appendix 11), the largest net losses shown by the Northern Highlands (12 squares) and Argyll West & Islands (10 squares), although some of these losses may have been a result of changes in detection rates between atlases (Balmer et al. 2013). Breeding abundance (Fig. D) increased most between 1988-91 and 2007-11 in the North East Coastal Plain, West Central Belt, and Eastern Lowlands; there were a mixture of increases and some decreases across the other NHZs ([Appendix S3](#)).

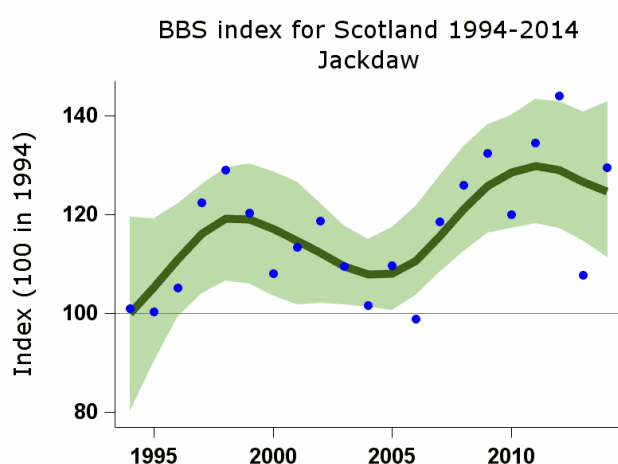


Fig. E Breeding Bird Survey trend for Jackdaw 1994-2014.

(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Drivers of population change

Although still the subject of legal control for the protection of arable crops and gamebirds, there is no evidence that such control limits population distribution or numbers. It is generally accepted that changes in the breeding population have been driven by changes in patterns of cultivation (Balmer et al. 2013). Past increases were greatest in pasture-dominated farmland (Gregory & Marchant 1996) but have since also been linked to arable and mixed farming areas, and pig rearing, which can provide a year-round food supply (Balmer et al. 2013). Reductions in grazing intensity and afforestation may be responsible for some localised losses in parts of Scotland. In recent decades, corvid populations may have benefitted from an increased food supply made available by the pheasant shooting industry (in the form of seed hoppers and road kills) but research is lacking.

UK, EU and global status and trends

The range in the rest of Britain and in Ireland has changed little since the late 1960s (Balmer et al. 2013; link to Britain and Ireland atlas maps). Abundance has shown some increase since the 1988-91 Bird Atlas survey, particularly across central and eastern England. Abundance increase in England as measured by the CBC/BBS surveys was sustained during the 1970s and 1980s (change 1967-2012 of +118%, 95% confidence limits 43-262%; Baillie et al. 2014), with the BBS trend since 1995 showing a significant 60% increase (Harris et al. 2015). Breeding abundance has increased even more rapidly in

Northern Ireland since 1995 (significant 106% increase from BBS) but less so in Wales (trend of +35% and non-significant; Harris et al. 2015). Breeding numbers across Europe have shown stability since 1980 ([PECBMS](#)).

BOCC4 status = **Green**

Birds Directive status = Annex 2.2

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is available from the [Baillie et al. 2014](#) and [BTO BirdFacts](#).



CARRION & HOODED CROWS

Corvus corone / *Corvus cornix*

Feeding habits

The eggs and young of wild birds form a substantial part of the mixed diet of these two ecologically similar opportunistic predators and scavengers, which are frequently specialist egg finders.

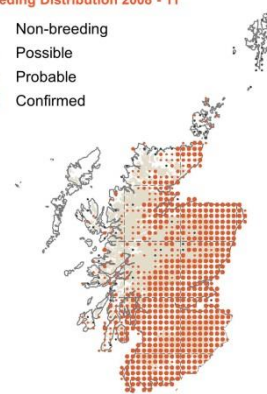
Distribution and abundance in Scotland

The Carrion Crow is a common breeding bird throughout south and east Scotland, but is uncommon in the north and west, and on most Scottish islands, where it is replaced by the Hooded Crow (Figs A & E). Carrion Crows generally favour the lowlands and avoid land above 750m (except the Cairngorm Plateau), whereas Hooded Crows occur more frequently in the uplands. Where the ranges of the two species meet, a hybridization zone exists, in which both species occur and interbreed. The centre of this zone currently extends from Kintyre in the south, in a north-east direction through the Cairngorms, north to Inverness and the Beaully Firth, Dornoch and Thurso in Caithness, with a few mixed pairs on Orkney (Forrester et al. 2007). Carrion and Hooded Crows were thought to breed in 688 and 655 10-km squares in 2007-11 respectively. Carrion Crows are most abundant in the lowlands of southern, central and eastern Scotland, and Hooded Crows most abundant in western coastal areas, Inner Hebridean islands and the Northern Isles (Fig. B and Fig. F).

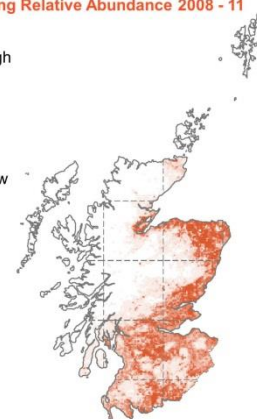


Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed

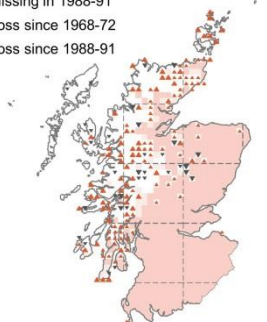


Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

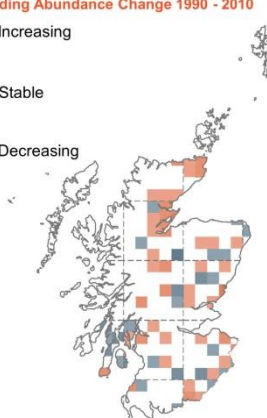
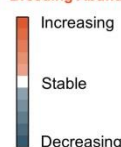


Fig. (A) Current distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Carrion Crow in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

Recent population trends in Scotland

Changes in distribution since the late 1960s reflect the expansion of the range of Carrion Crow north and west; the Scottish range of the species has expanded by 18%, with a net colonisation of 105 10-km squares (Fig. C).

The range of the Hooded Crow has shown little change since the 1960s (-2% and net loss of only 10 10-km squares; Fig. G); it is thought that the gains in range in north-east Scotland probably relate to records of hybrid birds (Balmer et al. 2013). Overall across Scotland, the breeding abundance of Carrion Crow increased by 5% between 1988-91 and 2007-11 (Fig. D), while that of the Hooded Crow decreased by -10% (Fig. H). The Scottish trend in breeding abundance between 1995 and 2013 from BBS is not significant for either species (Carrion Crow 0%, 95% confidence limits -22 to +29%; Hooded Crow -27%, 95% confidence limits -55 to +14%; Figs I and J; [Harris et al. 2015](#)).

Geographical variation in Scottish trends

Since the late 1960s, the range of Carrion Crow has increased by 10 or more 10-km squares in four NHZs, these accounting for more than 70% of the range increase (Fig. C): the Peatlands of Caithness & Sutherland (net gain of 24 squares); Argyll West and Islands (22 squares); Northern Highlands (19 squares); and North Caithness & Orkney (12 squares). The largest increases in breeding abundance between 1988-91 and 2007-11 occurred in North Caithness & Orkney, Wigtown Machairs & Outer Solway, the Peatlands of Caithness & Sutherland and the Eastern Lowlands (Fig. D; [Appendix 11](#)). The range of Hooded Crow shows a mixture of regional gains and losses since the late 1960s (Fig. G), with the largest losses from Coll, Tiree & the Western Isles ([Appendix 11](#)). The apparent gains in range in North East Coastal Plain probably relate to records of hybrid birds (Balmer et al. 2013). Atlas surveys suggest declines in abundance between 1988-91 and 2007-11 in Coll, Tiree & the Western Isles and a number of other NHZs (Fig. H; [Appendix S3](#)).

Drivers of population change

Both species were heavily controlled by gamekeepers and farmers during the 1800s. By the early 1900s, with a reduction in control, the Carrion Crow was common across lowland Scotland, with its range in the east as far north as Sutherland and Caithness (Forrester et al. 2007). The hybridization zone is thought to have moved north and west in recent decades, probably as a result of climate amelioration (Forrester et al. 2007), which appears to favour the Carrion Crow over the Hooded Crow (at least at altitudes below 300m). Both species are still controlled legally (Tapper 1992; Dick & Stronach 1999), which may reduce numbers

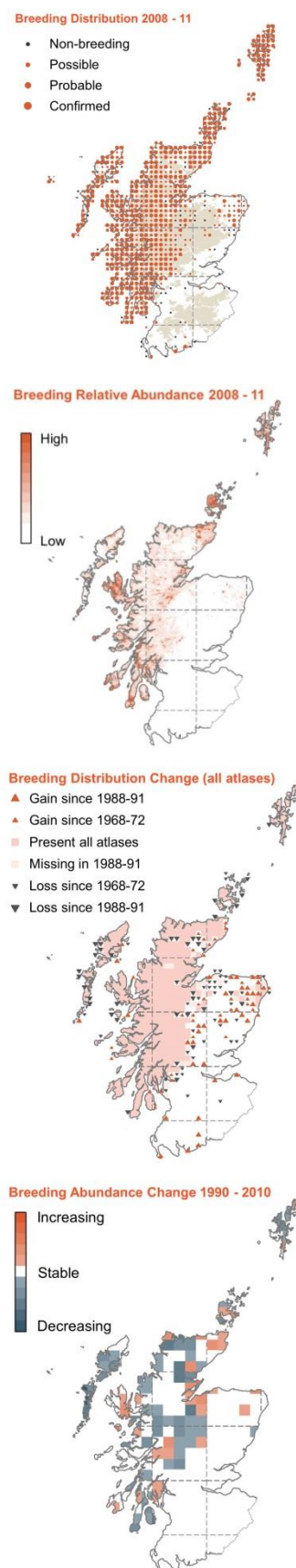


Fig. (E) Current distribution and (F) abundance, and (G & H) changes (1968-72 to 2007-11) for Hooded Crow in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

locally in some areas. In recent decades, corvid populations may have benefitted from an increased food supply made available by the pheasant shooting industry (in the form of seed hoppers and road kills) but research is lacking.

UK, EU and global status and trends

The range of the Carrion Crow in England and Wales is little changed since the late 1960s but, largely since the late 1980s, has increased by 25% in Ireland, through colonisation of the north-east coast (Balmer et al. 2013; link to [Britain and Ireland atlas maps](#)). The range of Hooded Crow has changed little in Ireland. Carrion Crow abundance increased markedly in eastern England between 1988-91 and 2007-11 ([Britain and Ireland atlas maps](#)). Overall abundance change in England as measured by the CBC/BBS surveys was 132% between 1967 and 2012, with some suggestion of a lower rate of increase since 2000 (Baillie et al. 2014). In contrast to the relative stability in Scotland, breeding abundance as measured by BSS (1995-2013) increased significantly in England (+24%) but not in Wales (+17%, 95% confidence limits -3 to +44%; Harris et al. 2015). The Hooded Crow has increased markedly in abundance in Ireland since the 1988-91 Bird Atlas (Balmer et al. 2013; link to [Britain and Ireland atlas maps](#)) and as measured by BBS (significant 150% increase 1995-2013; Harris et al. 2015). There has been widespread moderate increase of Carrion and Hooded Crows, taken together, across Europe since 1980 (PECBMS).

BOCC4 status = **Green**

Birds Directive status = Annex 2.2 (both species)

BirdLife EU status = LC / UR

IUCN global status = LC / UR

Demographic knowledge

Demographic information is available from the [Baillie et al. 2014](#), [BTO BirdFacts](#) and Forrester et al. 2007.

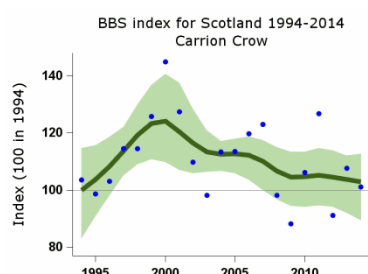


Fig. I Breeding Bird Survey trend for Carrion Crow 1994-2014.

(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

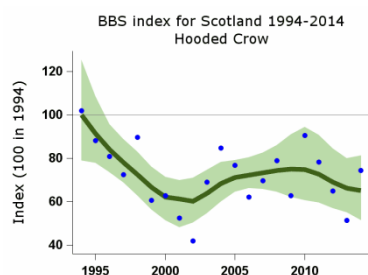


Fig. J Breeding Bird Survey trend for Jackdaw 1994-2014.

(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)



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RAVEN

Corvus corax

Feeding habits

A generalist predator and scavenger, for which the eggs and young of wild birds form part of the diet.

Distribution and abundance in Scotland

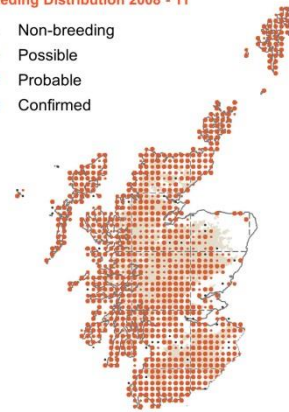
Present throughout most of Scotland, with the exception of the lowlands of the north east and Tayside. (Fig. A). Most abundant in the west of its Scottish range, including south-west Scotland, mainland Argyll, the Inner and Outer Hebrides and the Northern Isles (Fig. B). Thought to breed in 909 10-km squares in 2007-11.

Recent population trends in Scotland

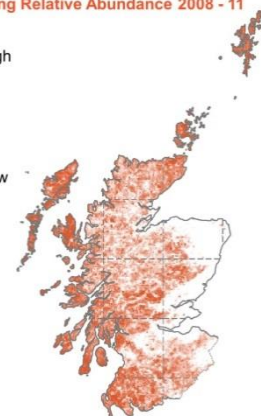
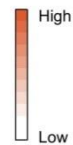
Since the late 1960s, the species has shown recovery of its range eastwards, particularly in south-east Scotland and the Central Belt, with much of that expansion occurring since the late 1980s (Fig. C). It remains largely absent from the lowlands of north-east Scotland however. Since the late 1960s the Scottish range has expanded by 28%, with a net colonisation of 197 10-km squares ([Appendix 11](#)). Breeding abundance has increased in many areas since the late 1980s (Fig. D; overall increase +93% since 1988-91). The national trend in raven breeding abundance (from BBS, Fig. E) showed some increase between 1994 and 2007, with some degree of stabilisation suggested subsequently. The overall change in abundance between 1995 and 2013 from BBS was +40% (lower and upper confidence limits -15 to +124%, so not significant over the whole period; Harris et al. 2015). The BBS trend may not be fully representative of change in breeding numbers however, as the methods do not allow breeding pairs to be distinguished from non-breeding 'floaters', numbers of which may not vary in direct proportion to the numbers of breeding pairs in a population, and because non-territorial individuals and family groups can move around large areas during the breeding season and after breeding (from late May onwards), with non-territorial pairs sometimes displaying well away from possible nest sites ([Roos et al. 2015](#)).

Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed

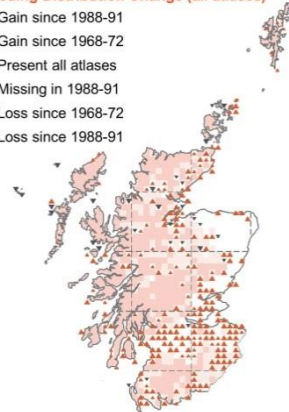


Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

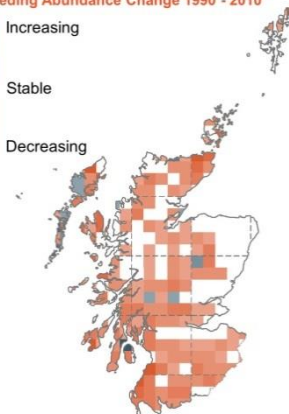
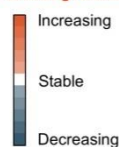


Fig. Relative abundance, distribution changes (1968-72 to 2007-11), and abundance change (1988-91 to 2007-11) for Raven in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

Geographical variation in Scottish trends

Since the late 1960s, range (at 10-km square resolution) has remained largely constant in eight NHZs, and increased in all the others ([Appendix 11](#)). The largest range changes occurred in the Eastern Lowlands (net of 50 colonised 10-km squares), West Central Belt (28 squares), Border Hills (19 squares) and Western Southern Uplands & Inner Solway (18 squares), with three more NHZs showing a net gain of 10 or more squares. Breeding abundance has increased in most areas since the late 1980s, most markedly in the Wigtown Machairs & Outer Solway Coast and North Caithness & Orkney ([Appendix S3](#)). The SRMS does not yet produce trends from local studies but these may be available in future (Roos *et al.* 2015).

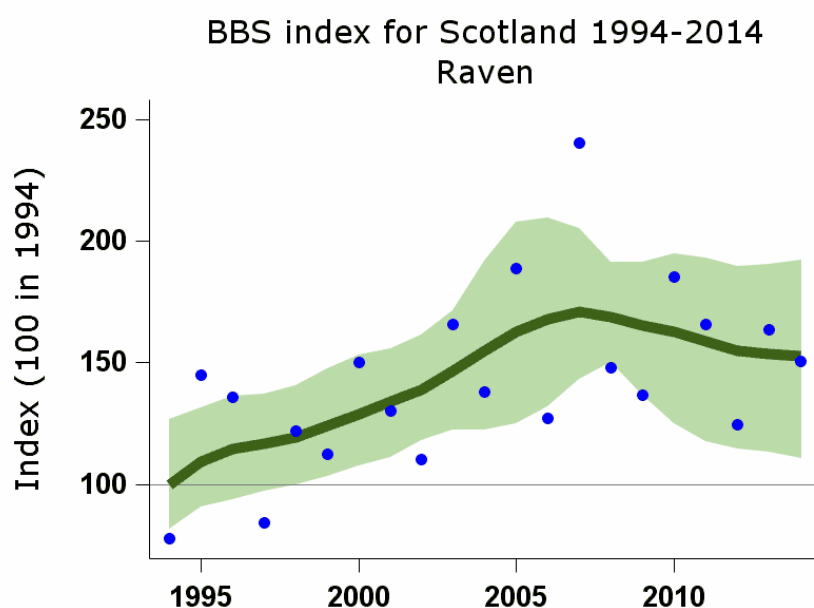


Fig. E Breeding Bird Survey trend for Raven 1994-2014.

(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Drivers of population change

The Raven was a common bird throughout Scotland, and the rest of Britain until the early 1800s, after which its numbers were heavily controlled by gamekeepers and some farmers (Forrester *et al.* 2007), with poisoning a key population driver in some areas (e.g. Strathspey; Weir 1978). Raven abundance was shown to be positively correlated with an index of grouse moor density but there were several possible explanations for the relationship, including persecution, moorland management and relationships with food availability (Gibbons *et al.* 1995). Continuing declines in southern and central Scotland between the 1960s and 1980s were attributed to increases in arable land and its management intensity, and conifer afforestation, both of which limited food availability for Ravens (Forrester *et al.* 2007). Organochlorine residues from sheep dip were found in Raven eggs but the egg shell thinning and marked effects on breeding success experienced by some other raptors during the 1950s and 1960s are not thought to have had any substantial effect on Raven populations (Ratcliffe 1970; Marquiss *et al.* 1978). By the end of the 1900s, Raven populations were benefitting from the protective conservation legislation and increases in sheep stocking rates and

deer populations providing increased carrion (Forrester et al. 2007). Licensed control of Ravens is legal currently but illegal control probably still occurs and it has been suggested that the latter may limit population recovery in parts of Scotland (particularly in the north east). Competitive relationships may exist between Ravens and other corvid species (e.g. the Raven population increased when Hooded Crows were culled on an Irish island; Bodey et al. 2009). In some areas, Raven breeding densities may be suppressed by the presence of other top predators, such as Golden Eagles (e.g. as suggested on Mull; Fielding et al. 2003).

UK, EU and global status and trends

The recovery of the breeding population (range and abundance) in Scotland reflects wider recovery eastwards across England, and colonisation in Ireland of the midlands and north east since the late 1960s (Balmer *et al.* 2013; link to [Britain and Ireland atlas maps](#)). Range has increased by 101% in England and Wales since the late 1960s (a net gain of 535 10-km squares occupied; mostly in central England, from the south coast northwards to Lancashire and Cheshire). The increases in abundance across many areas of Scotland are supplemented by increases across most of the current range in England and Wales, and across much of Ireland. Ravens remain largely absent in England east of a line from the Northumberland coast southwards to the Isle of Wight (refer to [mapstore maps](#)). Breeding numbers, as surveyed via BBS, show some signs of increase in England since 1994 (+112% but not significant) and suggest stability in Wales since that time, with the overall UK trend stable (Harris *et al.* 2015; link to BBS website for graphs).

BOCC4 status = **Green**

Birds Directive status = n/a

BirdLife EU status = LC

IUCN global status = LC

Demographic knowledge

Demographic information is available from the [SRMS annual reports](#) and [BTO BirdFacts](#).

4.4 Review of population trends for skua and gull predators of wild birds

ARCTIC SKUA

Stercorarius parasiticus

Feeding habits

Arctic Skuas obtain most of their food by piracy (mostly from other seabirds). They can also be an active predator of birds and small mammals, as well as scavenging, though they are much less dependent on fishery discards than other gulls and skuas.

Distribution and abundance in Scotland

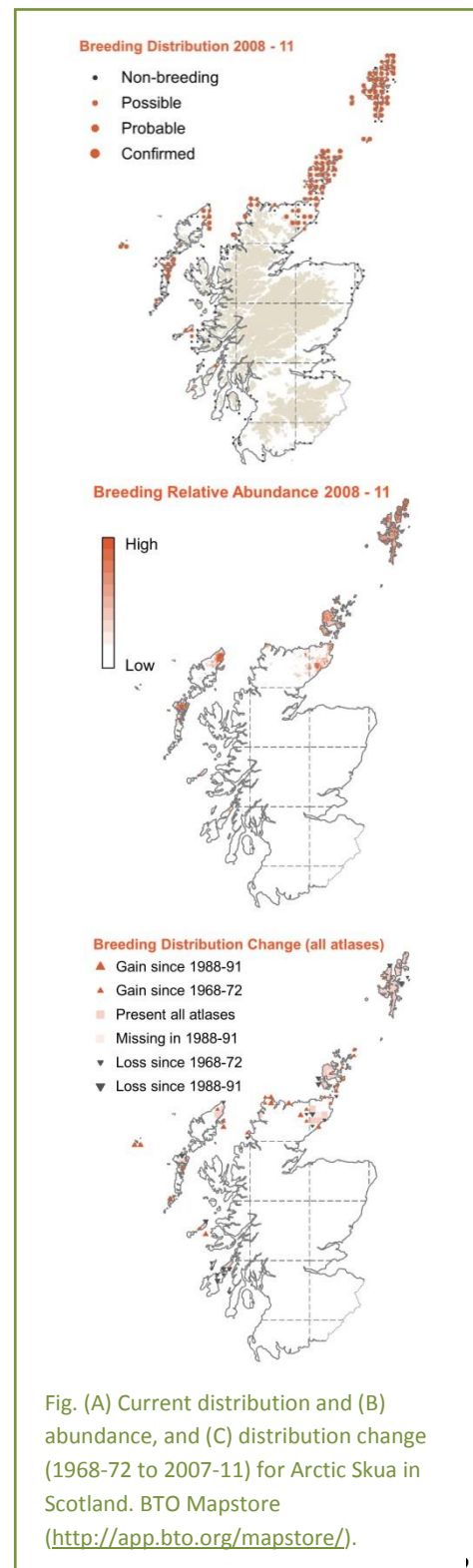
As a breeding bird, most Arctic Skuas are found in the Northern Isles with others on the Western Isles, locally in the Inner Hebrides and also in the far north of mainland Scotland (Figs A & B). Most nest in loose colonies or else as scattered pairs on moorland.

Recent population trends in Scotland

The number of 10-km squares in which breeding Arctic Skuas were recorded in Scotland increased by 14% between 1970 and 1990 but then decreased by 6% between 1990 and 2010. The net range change between 1970 and 2010 was an increase of 7% (Fig. C; [Appendix 11](#)). Changes in breeding population sizes suggest an increase of 106% between 1969-70 and 1998-2002, though that includes a decline of 37% between 1985-88 and 1998-2002 (Furness & Ratcliffe 2004a). The Seabird Monitoring Programme indicates a subsequent decrease in the British population of -74% between 2000 and 2013 (<http://jncc.defra.gov.uk/page-3201>).

Drivers of population change

Loss of nesting habitat through agricultural change and increasing numbers of predatory and competitive Great Skuas have been suggested as drivers of change (Lloyd *et al.* 1991). The former may have influenced local distribution but was thought unlikely to have driven any change in populations as alternative suitable areas have never been limited (Furness & Ratcliffe 2004a). Reduced availability of food (e.g. sandeels) for other seabirds has consequently led to reduced availability to kleptoparasitic skuas. This has caused foraging Arctic Skuas to spend more time away from their nests and consequently made their young more vulnerable to predation, notably by Great Skuas which, in turn with reduced availability of piratically sourced food,



have also become more predatory in nature (Furness 2007a).

British, Irish and European Trends

All Arctic Skuas breeding in Britain and Ireland are found in Scotland (Balmer *et al.* 2013).

There are no available population trends for Europe.

BOCC4 status = **Red**

Birds Directive status = n/a

BirdLife EU status = EN

IUCN global status = LC

GREAT SKUA

Stercorarius skua

Feeding habits

Great Skuas obtain food by piracy (mostly from other seabirds) and are effective scavengers, especially for fishery discards. They are also active predators of eggs, young and adult birds and small mammals.

Distribution and abundance in Scotland

As a breeding bird, most Great Skuas are found in the Northern Isles but are also widely distributed along the west coast and the Hebrides, with the most southerly confirmed breeding sites in Scotland being islands to the west of Mull (Staffa and Treshnish; Figs A & B). They can nest in extensive colonies (mostly in the Northern Isles) or as small groups or single pairs.

Recent population trends in Scotland

The number of 10-km squares in which breeding Great Skuas were recorded in Scotland increased by 97% between 1970 and 2010, including an increase of 42% between 1990 and 2010. Increases were in Orkney and throughout their west coast range (Fig. C; [Appendix 11](#)). Changes in breeding population sizes suggest an increase of 213% between 1969-70 and 1998-2002, of which 26% was 1985-88 and 1998-2002, indicating a slowing of the rate of increase during the later period (Furness & Ratcliffe 2004b). Numbers at larger colonies appear to have declined or stabilised in recent years, though some smaller colonies continue to grow and new sites colonised suggestive of redistribution away from the larger colonies (SMP <http://jncc.defra.gov.uk/page-2879>, Furness 2007b). The annual sample of Great Skua colonies monitored by the SMP is insufficient to produce reliable

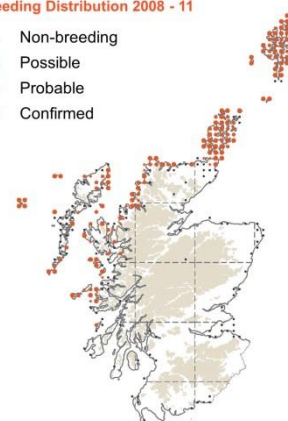
Drivers of population change

Great Skuas were rare breeding birds restricted to Shetland at the start of the 20th century. Increased protection and increased food availability through fishery discards were probably the principal drivers of their population increase which occurred through most of that century. Although shooting, including under licence, appears to have restricted the size of some colonies and may have prevented some others being established, a principal driver of some recent population declines is probably reduced food availability (i.e. a reversal of conditions that drove their increase), a factor which also could be operating away from their breeding areas (Furness & Ratcliffe 2004b). Declines at large colonies which are concurrent with

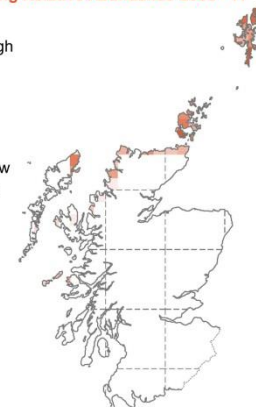


Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed



Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91

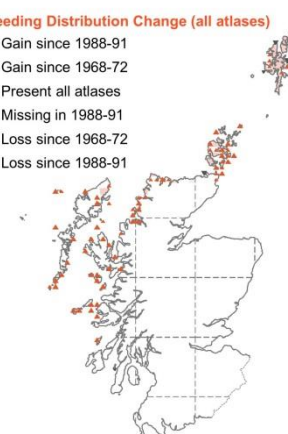


Fig. (A) Current distribution and (B) abundance, and (C) distribution change (1968-72 to 2007-11) for Great Skua in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

increases at some small ones and the establishment of new colonies strongly suggests that density-dependent processes have been operating which encourage emigration from, or discourage recruitment to, the larger colonies (Furness 2004).

British, Irish and European Trends

All Great Skuas breeding in Britain are found in Scotland (Balmer *et al.* 2013). The species has recently started breeding in Ireland, on islands off the coast of Northern Ireland (first nesting in 2010) and off the west coast (since the late 1990s) as far south as County Galway. There are no available population trends for Europe.

BOCC4 status = **Amber**

Birds Directive status = n/a

BirdLife EU status = LC

IUCN global status = LC

BLACK-HEADED GULL

Chroicocephalus ridibundus

Feeding habits

A generalist that forages within a wide range of habitats. It can be a predator of eggs and chicks but in most cases, these form a small proportion of the diet.

Distribution and abundance in Scotland

As a breeding bird, Black-headed Gulls occur throughout most of Scotland but are absent from quite extensive areas of the west and central Highlands (Fig. A). They can range widely and occur at considerable distances from breeding areas. They nest usually in colonies, where most are associated with water bodies, which can include small mires as well as the largest lochs. They are most abundant in eastern, central and southern Scotland (including the east Highlands and Southern Uplands; Fig. B).

Recent population trends in Scotland

Between 1970 and 2010, there was a net contraction of the Black-headed Gull breeding range of 38% in Scotland, of which 19% was between 1990 and 2010. General losses appear to have occurred throughout the breeding range but does include a few relatively large contiguous areas such as around the Firth of Clyde and in the upper Forth and Beaully catchments (Fig. C). Counts at breeding colonies indicate a decline in the breeding population of 62% since 1970 to the period 1998-2002 (Dunn 2004).

Drivers of population change

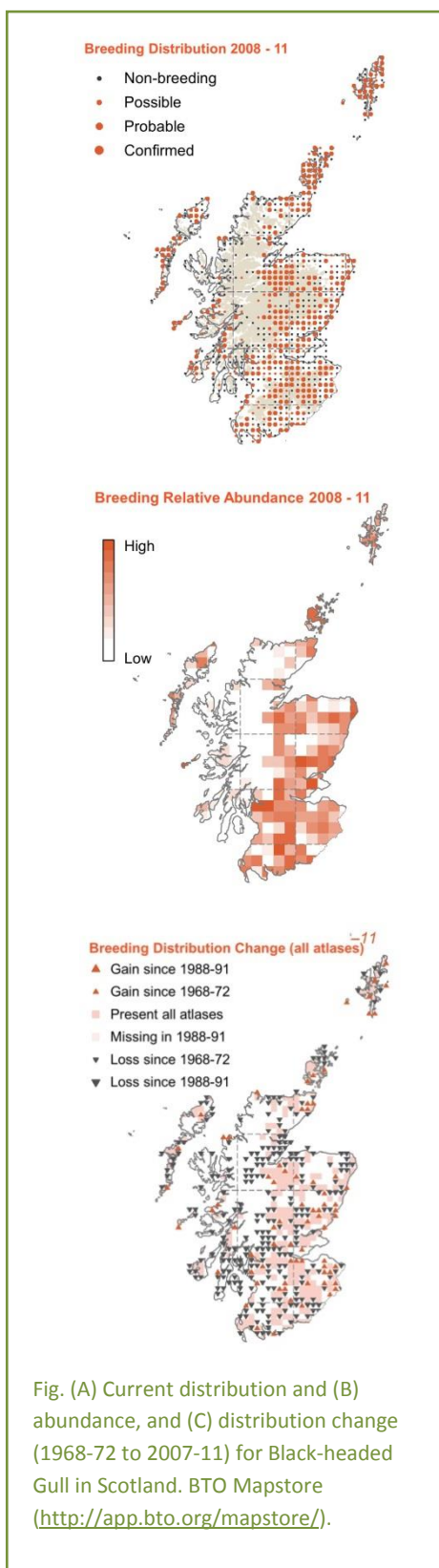
Some declines and abandonment of breeding colonies have been associated with drainage of wetlands and predation by American Mink, Otters and Foxes (Tasker 2007).

British, Irish and European Trends

Declines in the breeding range of Black-headed Gulls have also occurred through the rest of Britain and Ireland. Contraction of occupied range (as measured by presence in 10-km squares) of 11% in Britain and 55% in Ireland were reported between 1970 – 2010 with declines of relative abundance of -0.37 and -0.65 respectively (and index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013). Despite the overall net losses across Britain, many new areas were occupied by breeding birds since 1990, particularly in the English midlands and south-east. Counts of breeding birds at colonies indicate very little change in the breeding population between 1969-70 to 1998-2002 in Britain (just a 2% increase) and a slight increase in Ireland of 6% (Dunn 2004). The Seabird



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Monitoring Programme indicates an increase in the British population of 26% between 2000 and 2013 (<http://jncc.defra.gov.uk/page-3201>). As this contrasts with a range contraction, it appears that Black-headed Gulls are tending to breed in fewer, but larger colonies.

The population trend from western Europe indicates a decline of 37% between 1989 and 2013 (Fig. E; <http://www.ebcc.info/index.php?ID=587>). However, its current European Red List Status is as of 'Least Concern' in response to its extensive range across the continent and evidence of increases in some range states (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Amber**

Birds Directive status = Annex 2.2

BirdLife EU status = LC

IUCN global status = LC

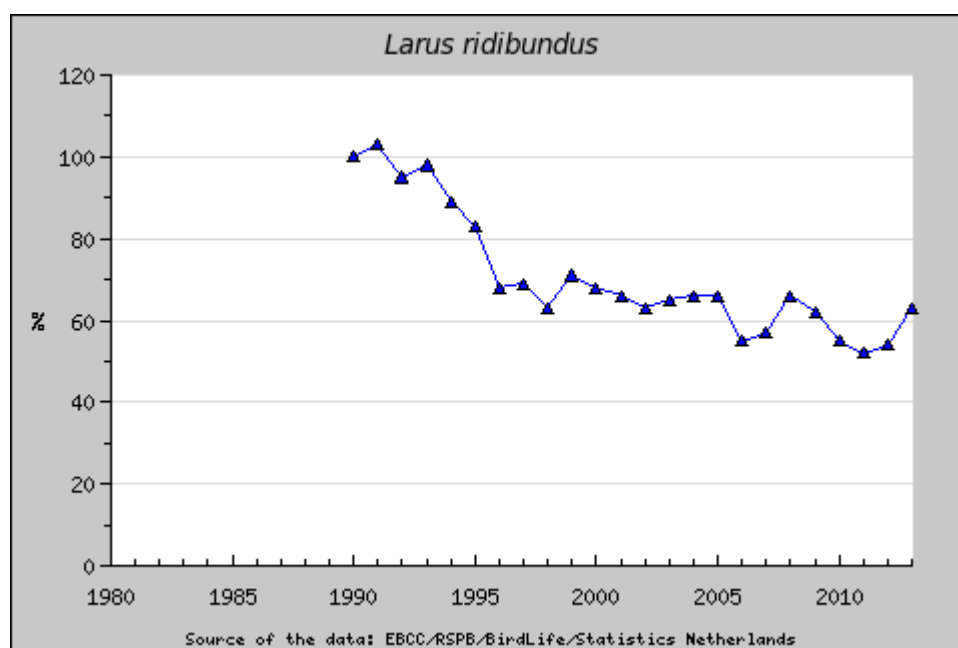


Fig. E. Changes in the abundance of breeding Black-headed Gull across western European between 1989 – 2013 (Pan European Common Bird Monitoring Scheme: <http://www.ebcc.info/pecbm.html>).

COMMON GULL

Larus canus

Feeding habits

Terrestrial foods include earthworms, beetles and other insects, as well as eggs and young of wild birds. Discarded fishery wastes can supplement natural food at sea.

Distribution and abundance in Scotland

As a breeding bird, Common Gulls occur throughout most of Scotland (Fig. A). They nest usually, though not exclusively in colonies, in a variety of environments including ground-nesting on open moorland, coastal dunes, urban roof-tops as well as by water bodies and other wetlands. They are least abundant approaching the border with England where they are a scarce and localised breeding bird (Fig. B).

Recent population trends in Scotland

Between 1970 and 2010, there was a small net contraction of the Common Gull breeding range of 7% in Scotland. Losses and gains appear to have occurred throughout the breeding range (Fig. C). Changes in breeding population sizes are available for coastal colonies only which suggest an increase of 35% between 1969-70 and 1998-2002 (Tasker 2004). Note, however, that the majority of Common Gulls breeding in Scotland are away from the coast and so that change may not be representative of the wider population.

Drivers of population change

For much of the 20th century, most populations of breeding gulls in Britain increased with those increases attributed widely to reduced exploitation (e.g. of eggs), reduced control, increased protection (legislation) and increased food availability (fishery discards, refuse tips and other garbage) (e.g. Lloyd *et al.* 1991). Some declines in recent decades have resulted from the reversal of some of those conditions which are thought to have led to the earlier increases. For Common Gulls in particular however, predation by American Mink has been associated with local declines and abandonment of some colonies (e.g. Craik 1997, Craik & Campbell 2000).

British, Irish and European Trends

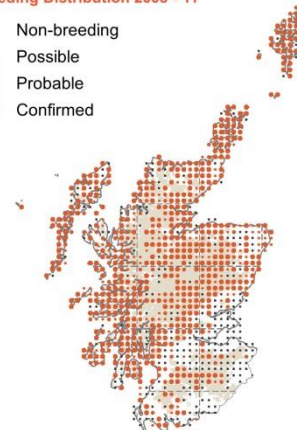
The vast majority of British Common Gulls nest in Scotland, and so not surprisingly, the 40-year change in distribution since 1970 is also a 7% decline. For the same reason, the change in relative abundance across Britain, a decline of -0.24 (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares), will largely be driven by changes in Scotland. In Ireland, there was a minor decline, of 3% in the number of 10-km squares



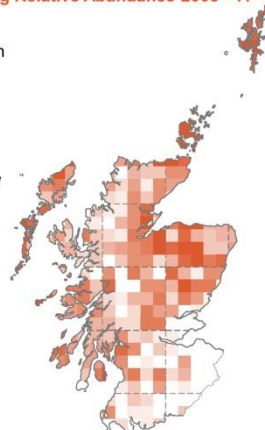
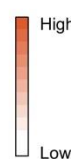
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Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed



Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91

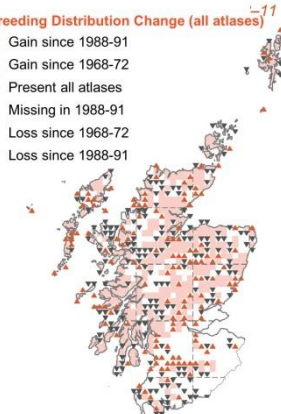


Fig. (A) Current distribution and (B) abundance, and (C) distribution change (1968-72 to 2007-11) for Common Gull in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

in which breeding was recorded between 1970 and 2010, with a change in the abundance index between 1990 and 2010 of -0.41 (Balmer *et al.* 2013).

There are no available trends for Common Gulls across Europe and its current Red List Status is as of 'Least Concern' in response to its extensive range across the continent

(<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Amber**

Birds Directive status = n/a

BirdLife EU status = LC

IUCN global status = LC

LESSER BLACK-BACKED GULL

Larus fuscus

Feeding habits

A generalist feeder in both the terrestrial and marine environments, it can be a predator of eggs, chicks and full grown birds. Other terrestrial foods include earthworms, beetles and other insects and garbage. Discarded fishery wastes can supplement natural food at sea and in the inter-tidal zone.

Distribution and abundance in Scotland

As a breeding bird, Lesser Black-backed Gulls occur around all coasts and also some inland areas, especially across the central belt (Fig. A). They can range widely and at considerable distances from breeding areas. They nest usually in colonies, which can be found in a variety of environments including islands, coastal dunes, urban roof-tops and open moorland. They are most abundant in central Scotland and on the Solway coast and they often nest in mixed colonies with other species of gull (Fig. B).

Recent population trends in Scotland

Between 1970 and 2010, there was a net contraction of the Lesser Black-backed Gull breeding range of 10% in Scotland of which 5% was between 1990 and 2010. Losses in range have been mostly in the Northern and Western Isles and on the west coast. In contrast, there have been expansions in central and south-west Scotland, particularly in inland and urban areas (Fig. C). Changes in breeding population sizes are available for coastal colonies only which suggest an increase of 57% between 1969-70 and 1998-2002 (Calladine 2004), despite the fact that most of the range contraction has also been in coastal areas.

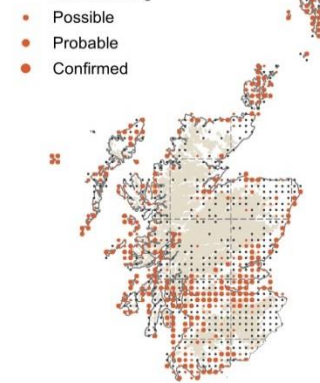
Drivers of population change

For much of the 20th century, most populations of breeding gulls in Britain increased with increases attributed widely to reduced exploitation (e.g. of eggs), reduced levels of control (culling), increased protection (legislation) and increased food availability (fishery discards, refuse tips and other garbage) (e.g. Lloyd *et al.* 1991). Some declines in recent decades have resulted from the reversal of some of those conditions (e.g. reduced availability of fishery discards, reduced use of landfill for refuse and targeted programmes of culling for nature conservation and public health reasons) and increased predation by American Mink and possibly other native mammalian predators (Ratcliffe 2004).

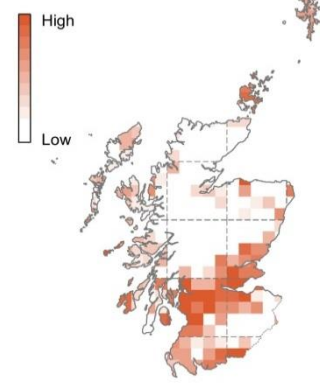
British, Irish and European Trends



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Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

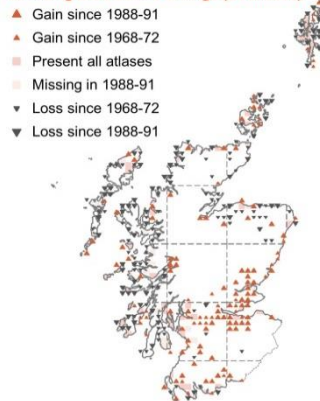


Fig. (A) Current distribution and (B) abundance, and (C) distribution change (1968-72 to 2007-11) for Lesser Black-backed Gull in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

The breeding range of Lesser Black-backed Gulls has increased across Britain (as measured by presence in 10-km squares) by 65% between 1970 and 2010 but by just 3% in Ireland. In common with Scotland, much of the expansion in Britain has been in inland and urban areas. Despite the increase in range size, the indices of relative abundance suggested declines of -0.11 and -0.44 in Britain and Ireland respectively (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013). Counts at coastal colonies indicate an increase in the breeding population for the whole of Britain of 77% between 1969-70 and 1998-2002 and 84% in Ireland (Calladine 2004). The Seabird Monitoring Programme shows a subsequent decrease in the British population of -48% between 2000 and 2013 (<http://jncc.defra.gov.uk/page-3201>). There are no available population trends for Europe. The species' current European Red List Status is as of 'Least Concern' in response to its extensive range across the continent and evidence of increases (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Amber**

Birds Directive status = Annex 2.2

BirdLife EU status = LC

IUCN global status = LC

HERRING GULL

Larus argentatus

Feeding habits

A generalist feeder in both the terrestrial and marine environments, it can be a predator of eggs, chicks and full grown birds. Other terrestrial foods include earthworms, beetles and other insects and garbage. Discarded fishery wastes can supplement natural food at sea and in the inter-tidal zone.

Distribution and abundance in Scotland

Breeding Herring Gulls occur around all coasts and also some inland areas, especially across the central belt (Fig. A). They can range widely and occur at considerable distances from breeding areas. They nest usually in colonies, which can be found in a variety of environments including islands, coastal cliffs and urban roof-tops. They are most abundant along the east coast and on the Solway coast and they often nest in mixed colonies with other species of gull (Fig. B).

Recent population trends in Scotland

The number of 10-km squares occupied by breeding Herring Gulls in Scotland in 2008-11 was about the same as in 1968-72. Within that period, there had been a 5% decrease between 1970 and 1990 which was then followed by a 6% increase between 1990 and 2010. There had been some losses of range particularly on the west coast and islands but these had been matched by increases particularly on the east coast and in the central belt. (Fig. C). Changes in breeding population sizes are available for coastal colonies only which suggest a decrease of 23% between 1969-70 and 1998-2002 (Madden & Newton 2004).

Drivers of population change

For much of the 20th century, most populations of breeding gulls in Britain increased with increases attributed widely to reduced exploitation (e.g. of eggs), reduced levels of control (culling), increased protection (legislation) and increased food availability (fishery discards, refuse tips and other garbage) (e.g. Lloyd et al. 1991). Some declines in recent decades have resulted from the reversal of some of those conditions (e.g. reduced availability of fishery discards, reduced use of landfill for refuse and targeted programmes of culling) and increased predation by American Mink and possibly other native mammalian predators (Ratcliffe 2004). Botulism, a condition whereby birds are poisoned by toxins produced by a bacterium and is often associated with



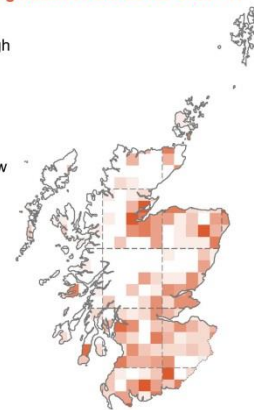
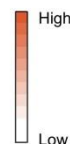
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Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed



Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91

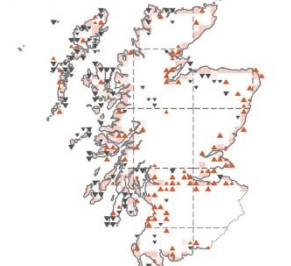


Fig. (A) Current distribution and (B) abundance, and (C) distribution change (1968-72 to 2007-11) for Herring Gull in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

rubbish tips is thought to have influenced some local Herring Gull colonies (Madden & Newton 2004).

British, Irish and European Trends

The breeding range of Herring Gulls has increased across Britain (as measured by presence in 10-km squares) by 38% between 1970 and 2010 but declined by 28% in Ireland. Much of the expansion in Britain has been in inland and urban areas. Despite the increase in range size, the indices of relative abundance suggested declines of just -0.02 in Britain but -0.40 in Ireland (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 – 2010 (Balmer et al. 2013). Counts at coastal colonies indicate a decrease in the breeding population for the whole of Britain of 50% between 1969-70 and 1998-2002 in Britain (just a 2% increase) and a decrease of 90% in Ireland (Madden & Newton 2004). The Seabird Monitoring Programme indicates a subsequent decrease in the British population of 30% between 2000 and 2013

(<http://jncc.defra.gov.uk/page-3201>). There are no available quantitative population trends for Europe. Herring Gulls are believed to have undergone moderately rapid declines across other rarer states in Europe and are therefore classified as Near Threatened.

(<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Red**

Birds Directive status = Annex 2.2

BirdLife EU status = VU

IUCN global status = LC

GREAT BLACK-BACKED GULL

Larus marinus

Feeding habits

A generalist feeder in both the terrestrial and marine environments, it can be a predator of eggs, chicks and full grown birds. Discarded fishery wastes can supplement natural food at sea and in the inter-tidal zone with other refuse supplementing natural foods in the terrestrial environments.

Distribution and abundance in Scotland

As a breeding bird, Great Black-backed Gulls occur around all coasts and also at a few inland sites (Fig. A). They can range widely and occur at considerable distances from breeding areas. They nest usually in colonies, which can be found in a variety of environments including islands, coastal cliffs and urban roof-tops. They are most abundant in the Northern Isles and islands off the west coast and they can nest in mixed colonies with other species of gull (Fig. B).

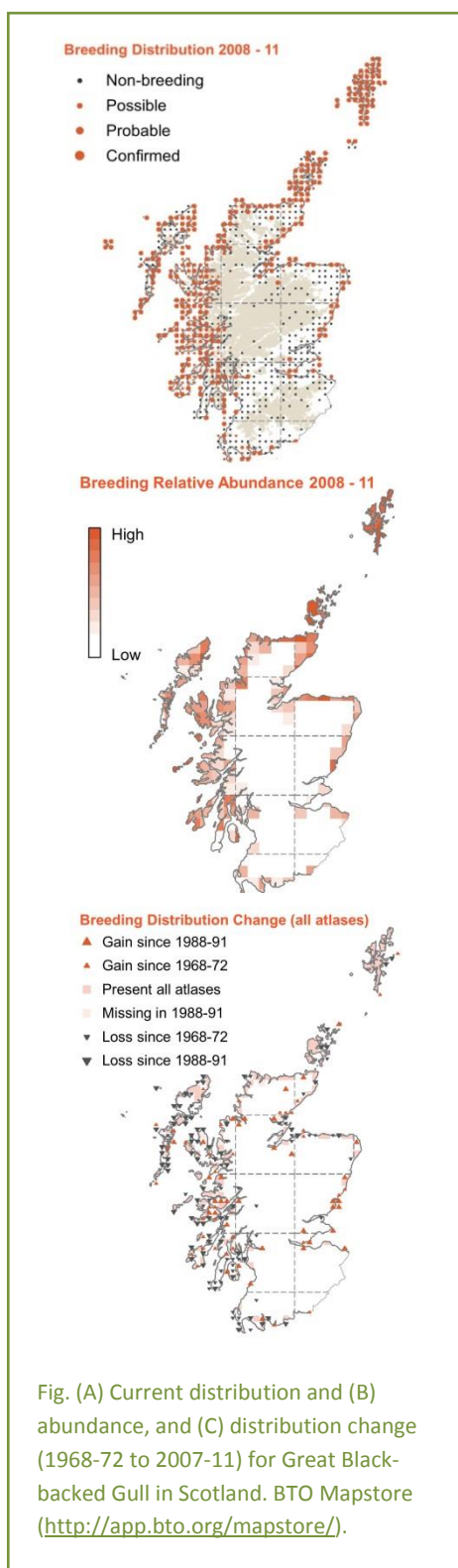
Recent population trends in Scotland

Between 1970 and 2010, there was a net contraction of the Great Black-backed Gull breeding range of 10% in Scotland of which 9%, the majority, was between 1990 and 2010. Losses in range have been mostly on and off the west coast. In contrast, there have been some expansions on the east coast (Fig. C). Changes in breeding population sizes are available for coastal colonies only which suggest a decrease of 7% between 1969-70 and 1998-2002 (Reid 2004). As most breeding Great Black-backed Gulls are coastal, that figure is likely to be representative of Scotland as a whole.

Drivers of population change

For much of the 20th century, most populations of breeding gulls in Britain increased with increases attributed widely to reduced exploitation (e.g. of eggs), reduced levels of control (culling), increased protection (legislation) and increased food availability (fishery discards, refuse tips and other garbage) (e.g. Lloyd et al. 1991). Some declines in recent decades have resulted from the reversal of some of those conditions (e.g. reduced availability of fishery discards, reduced use of landfill for refuse and targeted programmes of culling) and increased predation by American Mink and possibly other native mammalian predators (Ratcliffe 2004). Predation by and competition from Great Skuas has been linked to declines in the Northern Isles (Zonfrillo 2007).

British, Irish and European Trends



The breeding range of Great Black-backed Gulls has increased across Britain (as measured by presence in 10-km squares) by 5% between 1970 and 2010 but declined by 30% in Ireland. Indices of relative abundance suggested declines of -0.16 and -0.29 in Britain and Ireland respectively (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer et al. 2013). Counts at coastal colonies indicate a decrease in the breeding population for the whole of Britain of 2% between 1969-70 and 1998-2002 and 28% in Ireland (Calladine 2004). The Seabird Monitoring Programme indicates a subsequent decrease in the British population of -24% between 2000 and 2013 (<http://jncc.defra.gov.uk/page-3201>). There are no available population trends for Europe. The species' current European Red List Status is as of 'Least Concern' in response to its extensive range across the continent and evidence of increases (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Amber**

Birds Directive status = Annex 2.2

BirdLife EU status = LC

IUCN global status = LC

4.2 Review of population trends for wild bird prey: focal species



BLACK GROUSE

Tetrao tetrix

Distribution and abundance

Black Grouse are year-round residents in the uplands and their margins where they favour a mix of moorland, marginal farmland, woodland edge and young woodland. They were considered to breed in 353 10-km squares in Scotland during 2008-11 (Fig. A). Highest densities were found in the southern, eastern and central Highlands, an area that also defines their most extensive continuous range (Fig. B). They were absent from most islands and much of the west Highlands.

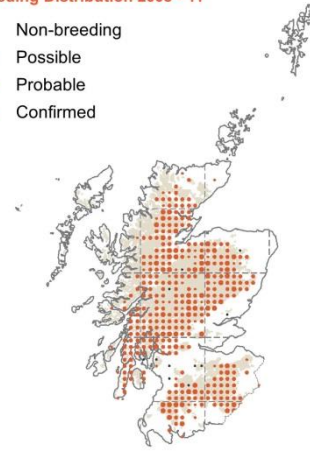
Changes in distribution and abundance

Atlas data

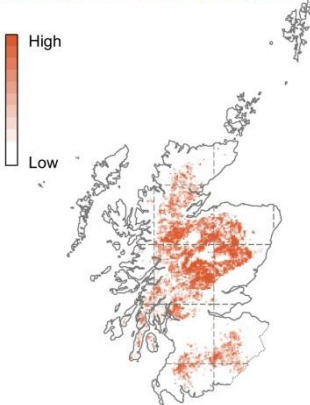
Between 1970 and 2010, there was a net contraction of the Black Grouse breeding range of 16% (66 10-km squares) in Scotland (7% since 1988-91). Most of the losses were around the periphery of the Southern Uplands (including Galloway) and the eastern Highlands (Fig. C). Within that same period, a small number of squares appear to have been colonised, perhaps reflecting the ephemeral nature of some of the habitat complexes that Black Grouse require (notably where that includes young woodland). The changes in abundance between 1990 - 2010 show a similarly mixed pattern (Fig. D), though there has been a similar net decline across Scotland. Colonisation of Arran was largely, or completely the result of releasing birds there. That island is now probably the

Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed

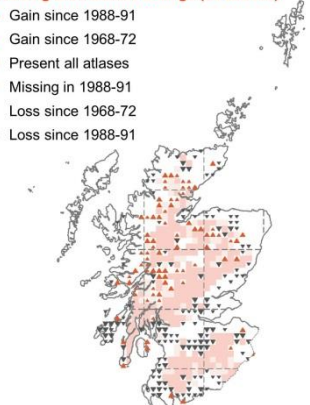


Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

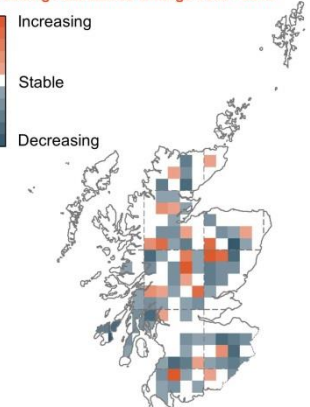
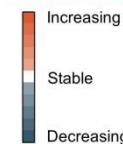


Fig. Current (A) distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Black Grouse in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

only one with resident Black Grouse (note the losses from Islay; Fig. C; [Appendix 11](#)).

Black Grouse Study Groups

Black Grouse are not monitored by the Breeding Bird Survey as they are encountered in too few of the randomly selected 1-km squares that are covered by volunteer surveyors. However, there is a number of local and regional study groups (BGSs) dedicated to the species and have monitored the number of lekking (displaying) males (Fig. E). Note that many, though not all male Black Grouse display at communal sites (leks), the locations of which can persist over many years.

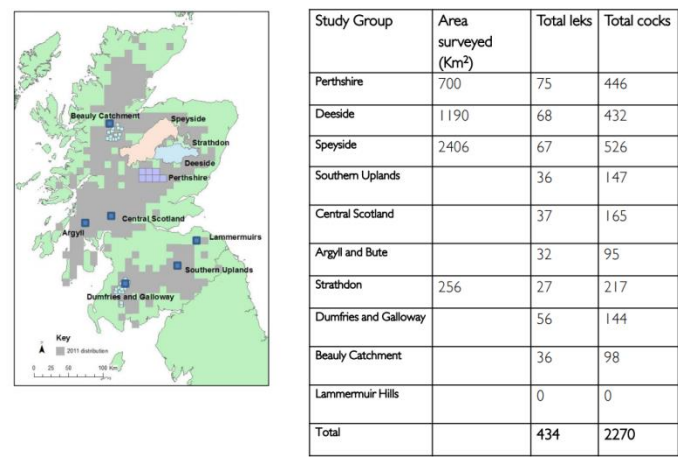


Fig. E. Areas where Black Grouse Study Groups (BGSs) have counts of displaying males in 2013. The extent of the study areas for Perthshire, Deeside and Speyside are indicated on the map. The general locations of other study areas are indicated by blue squares. The grey shaded area represents the distribution of Black Grouse in Scotland (after Balmer *et al.* 2013).

The longest run of data is from the Perthshire BGS which recorded 900 males in 1990, declining to about one-third of that number by 2002 but followed by some subsequent recovery. Other groups have not yet been able to collect such a long run of data and any general trends are not yet apparent (Fig. F). Data from the BGSs have yet to be subject to a robust analysis that takes into account annual variations in survey effort and coverage; the summary data is presented here to highlight its potential value and the generality of some recorded changes.

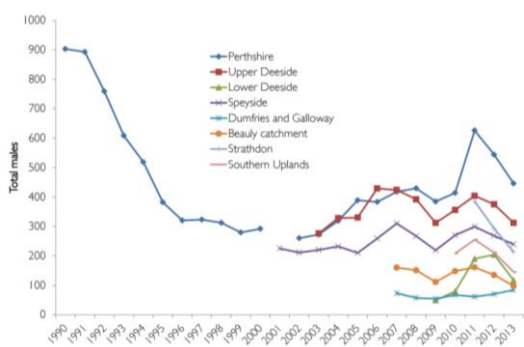


Fig. F. Changes in numbers of lekking Black Grouse males reported in eight areas surveyed by Black Grouse study Groups.

Other sources of information

Black Grouse were formerly widespread and present in all parts of Scotland except the Outer Hebrides and Northern Isles (Grant 2007). The number of birds shot on sporting estates declined by about 90% between the late 19th century and 1990 and provides an index for a long term population decline which was greater in the west of Scotland than in the east (Baines & Hudson 1995). The most

recent national survey of Black Grouse, in 2005, indicated a statistically significant decline in the number of displaying males of 29% across Scotland since the first such survey in 1995-96 (Sim *et al.* 2008). Regional declines (in declining proportions) were southeast Scotland (-69%), southwest Scotland (-49%), north Scotland (-16%) and northeast Scotland (-9%), though the changes in the latter two regions were not statistically significant (Sim *et al.* 2008).

British, Irish and European trends

Declines in the range and abundance of Black Grouse have also occurred through the rest of Britain (the species has always been absent from Ireland). Contraction of occupied range (as measured by presence in 10-km squares) of 29% in Britain was reported between 1970 – 2010 and there was a decline in relative abundance of -0.24 (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 – 2010 (Balmer *et al.* 2013). Most losses were from Wales, Cumbria and the central and southern Pennines with the species lost from south-west England by 1990. Present in most English counties in the early 20th century, the species has been subject to a long term contraction of range and population decline (Brown & Grice 2005).

Black Grouse has been subject to population declines and range contractions across a number of range states in Europe (Tucker & Heath 1994). However, its current European Red List Status is as of 'Least Concern' in response to its extensive range across the continent and evidence of increases in some range states (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Red**

Birds Directive status = Annex 2.2

BirdLife EU status = LC

IUCN global status = LC



CURLEW

Numenius arquata

Distribution and abundance

Breeding Curlew are widely distributed across Scotland (Fig. A) and considered to breed in 819 10-km squares during 2008-11. The highest densities were in the eastern lowlands and upland margins, the Northern Isles, Southern Uplands and some of the Inner Hebrides (Fig. B). They were absent, or present at low densities, across many parts of the western and central Highlands. Curlews are predominantly coastal outside of the breeding season.

Changes in distribution and abundance

Atlas data

Between 1970 and 2010, the breeding range of Curlew contracted by 14% (132 10-km squares) in Scotland, much of which (11%) occurred between 1990 and 2010 (Fig. C). Although complete losses have been largely restricted to the west Highlands, there have been widespread reductions in their abundance across the majority of the remainder of their range (a pattern that is very similar to that for Lapwing; Fig. D). Interestingly, there are areas where some increases appear to have occurred, notably the Western Isles but also other areas within the Highlands (Figs C & D; [Appendix 11](#)).

Breeding Bird Survey data

The BBS has sampled an annual average of 128 1-km squares in Scotland in which Curlews have been recorded between 1994 and 2014. These indicate a general decline in abundance of 55% which was statistically significant (95% confidence interval of change -63% to -47 %) during that 20 year period (Fig. E).

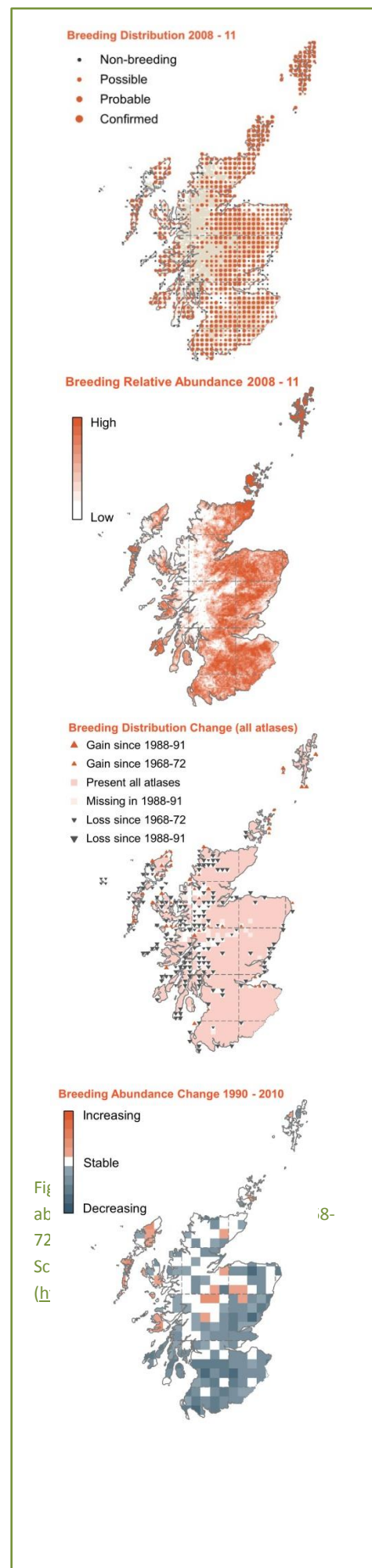


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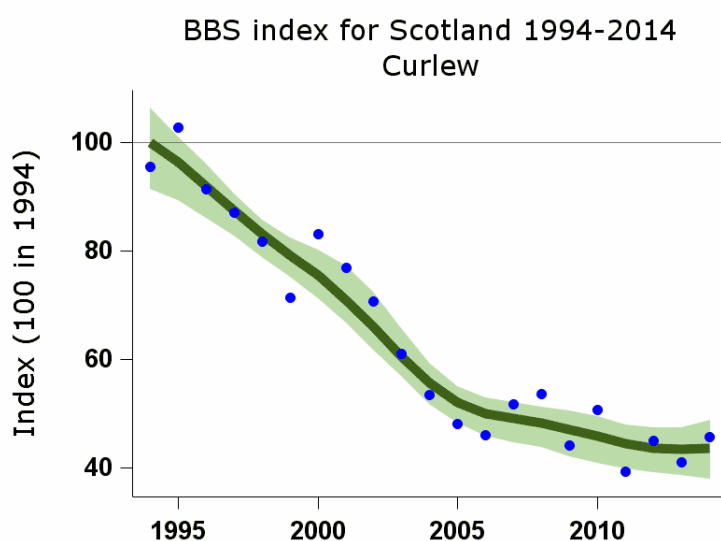


Fig. E Breeding Bird Survey trend for Curlew 1994-2014.
 (Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Other sources of information

Curlews are believed to have been widespread across Scotland in the 19th century but an expansion of their breeding range included more lowland areas in the early 20th century. Any decline in populations was not detected until the end of the 20th century, there being little substantive information on breeding numbers and densities before the 1990s (Bainbridge 2007).

Retrospectively, however, it was estimated that about 5000 pairs of Curlew were lost in southern Scotland in response to habitat loss to afforestation in southern Scotland since the late 1940s (Ratcliffe 2007). Regional surveys suggested declines in two upland regions (west Sutherland flows and south Scotland) of about half between the 1980s and around 2000 but did not detect a statistically significant change in four other areas (Sim *et al.* 2005). In contrast to the more widespread declines, increases were reported in some Tayside study areas between 1992 and 2012 (Davies *et al.* 2014) supporting the evidence that declines have not been universal across Scotland.

British, Irish and European trends

Declines in the range and abundance of breeding Curlew have also occurred through the rest of Britain and Ireland. Contraction of occupied range (as measured by presence in 10-km squares) of 17% in Britain and 78% in Ireland were reported between 1970 and 2010 with declines of relative abundance of -0.19 and -0.73 respectively (and index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013).

A decline of 42% is reported across Europe (data largely from north and western Europe) between 1980 and 2013 (Fig. F; <http://www.ebcc.info/index.php?ID=587>). This widespread shorebird is undergoing rapid population declines across the European part of its extremely large global range. It is therefore classified as Vulnerable in both Europe and the EU27 (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Red**

Birds Directive status = Annex 2.2

BirdLife EU status = VU

IUCN global status = NT

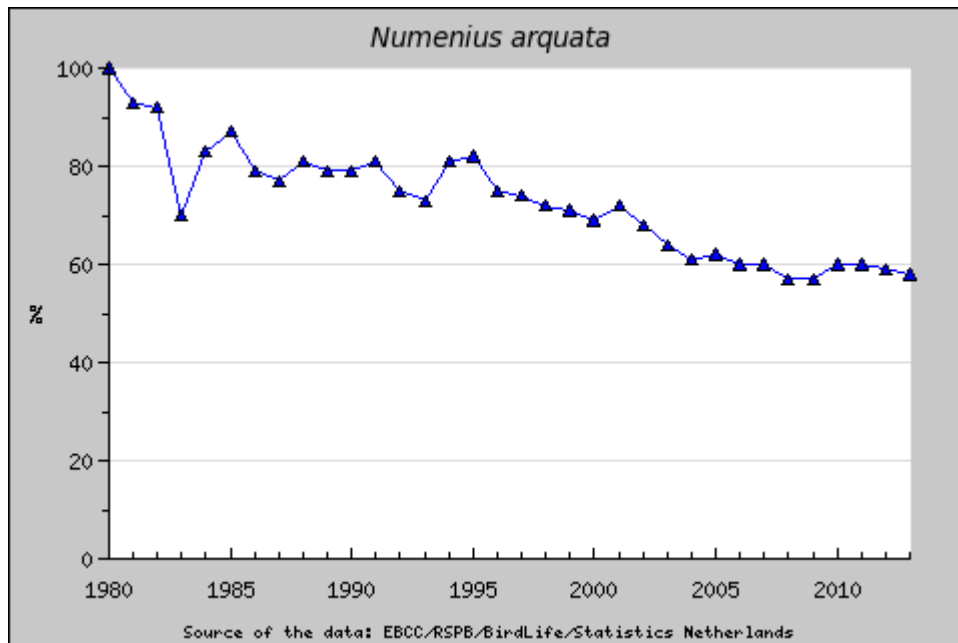


Fig. F. Changes in the abundance of breeding Curlew across European farmland between 1980 and 2013 ([Pan European Common Bird Monitoring Scheme: http://www.ebcc.info/pecbm.html](http://www.ebcc.info/pecbm.html)).



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GOLDEN PLOVER

Pluvialis apricaria

Distribution and abundance

As a breeding bird, Golden Plovers are widespread in the uplands (in the broadest sense of their definition) of Scotland occurring across the Highlands, all island groups and the Southern Uplands (Fig. A). They were considered to breed in 526 10-km squares during 2008-11. Highest densities were in the peatlands of Caithness and Sutherland, the Western Isles, Shetland and the higher ground of the central and eastern Highlands (Fig. B). The majority of Golden Plovers are absent from their breeding areas outside of the breeding season.

Changes in distribution and abundance

Atlas data

Between 1970 and 2010, the breeding range of Golden Plover in Scotland contracted by 20% (135 10-km squares; 13% since 1988-91). Complete losses were concentrated in the Southern Uplands and along the eastern and southern boundaries of the Highlands (Fig. C). Although there has been an overall decline in distribution and abundance across Scotland, there was some marked regional variations with increases and stability also apparent in a number of areas (Fig. D; [Appendix 11](#)).

Breeding Bird Survey data

The BBS has sampled an annual average of 39 1-km squares in Scotland in which Golden Plover have been recorded between 1994 and 2014. These indicate a general decline in abundance of 25% (95% confidence interval of change -44% to -3 %) during that 20 year period (Fig. 3.2.2). Although the change is marginally statistically significant only (as the 95% confidence intervals approach zero, or no change), the relatively

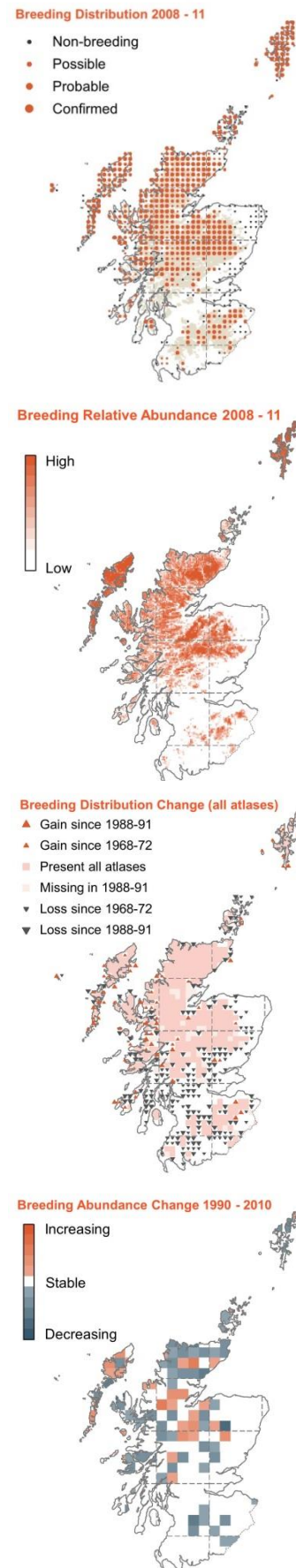


Fig. Current (A) distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Golden Plover in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

small sample size of squares including the species will give limited power to detect significant differences.

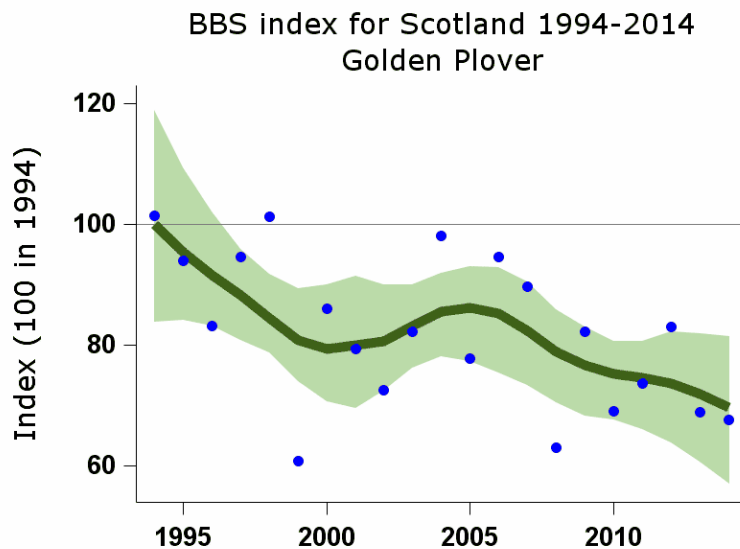


Fig. E Breeding Bird Survey trend for Golden Plover 1994-2014.
(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Other sources of information

The Golden Plover appears to have long been a widespread and even common breeding bird on the moors and mires of Scotland, at least in recorded times (Thompson 2007). Some regional surveys provide further evidence to support an overall decline in recent decades but with some local exceptions that includes increases within some areas as well as others with no change (e.g. Sim *et al.* 2005, Bellamy & Eaton 2009).

British, Irish and European trends

Declines in the range and abundance of breeding Golden Plover have also occurred through the rest of Britain and Ireland. Contraction of occupied range (as measured by presence in 10-km squares) of 20% in Britain and 50% in Ireland were reported between 1970 and 2010 with declines of relative abundance of -0.13 and -0.27 respectively (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013).

A 'European' trend, which is derived from Fenno-Scandinavian countries only, suggests relatively little change in the abundance of breeding Golden Plovers since the 1980s (Fig. F). There is some suggestion that there may have been a decline in the 1990s followed by some recovery, however (<http://www.ebcc.info/index.php?ID=587>). Its current European Red List Status is as of 'Least Concern' in response to its extensive range across the continent and evidence of increases in some range states (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Green**

Birds Directive status = Annexes 1 and 2.2

BirdLife EU status = LC

IUCN global status = LC

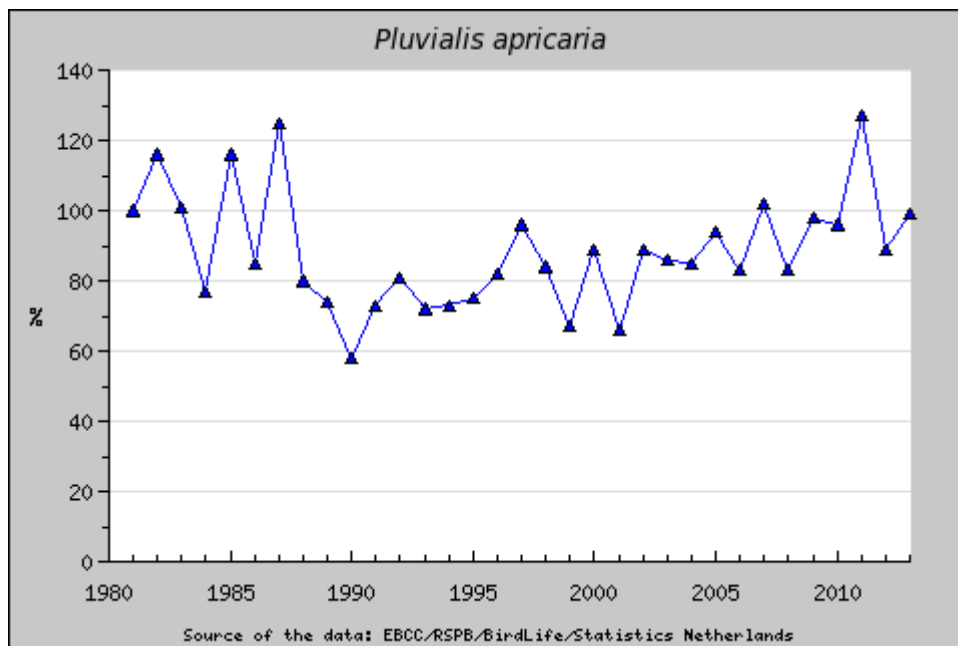


Fig. F. Changes in the abundance of breeding Golden Plover across northern Europe between 1980 and 2013 ([Pan European Common Bird Monitoring Scheme: http://www.ebcc.info/pecbm.html](http://www.ebcc.info/pecbm.html)).



GREY PARTRIDGE

Perdix perdix

Distribution and abundance

Grey Partridge are largely restricted to eastern Scotland, predominantly in the lowlands but extending to the upland margins in some areas, with an apparently isolated outpost in Ayrshire and a very few more isolated occurrences elsewhere. Breeding was confirmed in 218 10-km squares during 2008-11 (Figs A & B).

Changes in distribution and abundance

Atlas data

Between 1970 and 2010, the breeding range of Grey Partridge contracted by 54% (257 10-km squares) in Scotland, of which much was between 1990 and 2010 (39%; Fig. C). Extensive losses have occurred in the western part of the central belt and south through Lanarkshire, Ayrshire and Dumfries and Galloway. Further losses are apparent around the upland margins of the east Highlands (Fig. C; [Appendix 11](#)). Declines in breeding abundance have occurred throughout the range (Fig. D; [Appendix S3](#)) with an overall decrease of -74% between 1988-91 and 2008-11.

Breeding Bird Survey data

The BBS has sampled an average of 21 1-km squares in Scotland in which Grey Partridge have been recorded between 1994 and 2014. These indicate a general and marked decline in abundance of 76 % (95% confidence interval of change -98% to -65 %) during that 20 year period (Fig. E). Although the sample of BBS squares that include Grey Partridge is quite small, and therefore any derived trend should be treated with caution, the change is statistically significant and adds support to declines reported by other surveys.

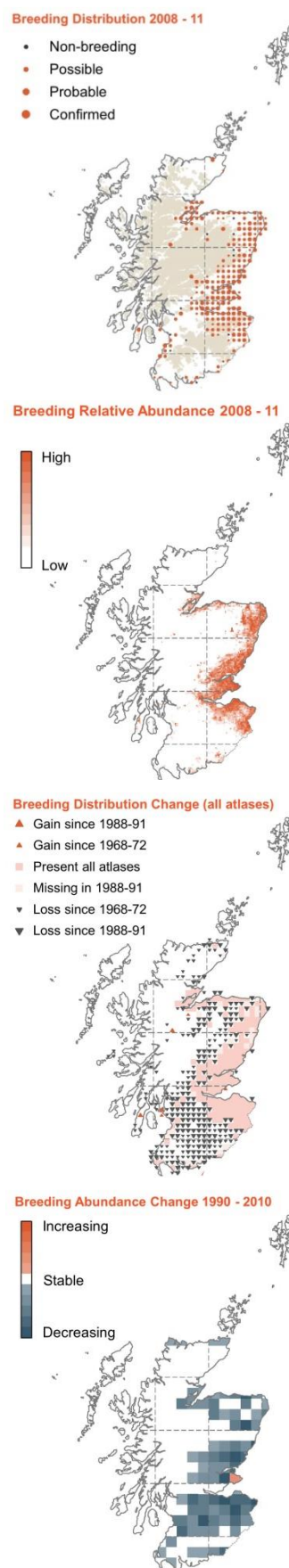


Fig. Current (A) distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Grey Partridge in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

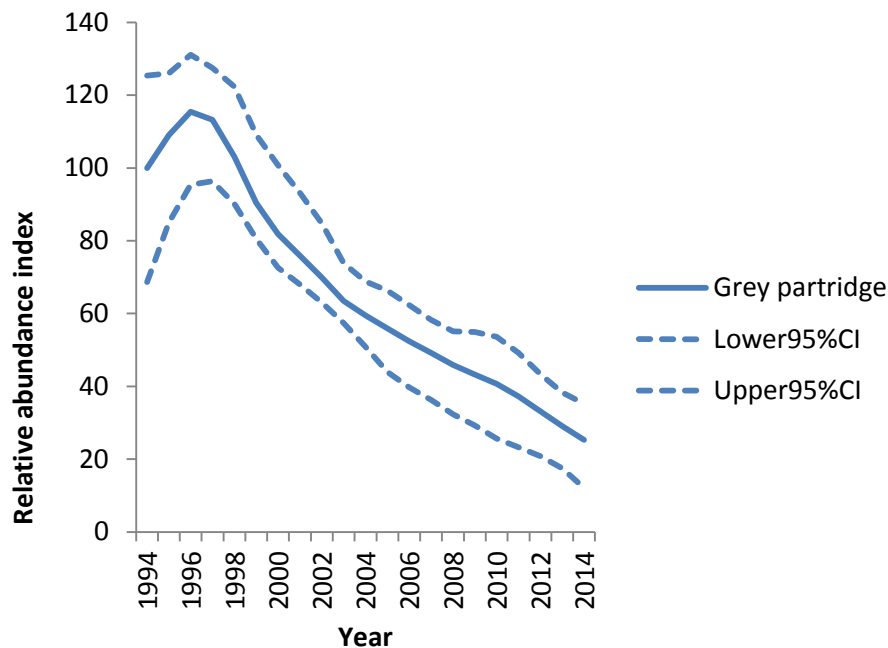


Fig. E. Changes in the abundance index for breeding Grey Partridge in Scotland derived from BBS data between 1994 and 2014. The smoothed trend line shows changes in the annual index of abundance relative to the first year of that survey (1994 when the index is given as 100) (Source – Bird Trends or Harris *et al.*).

Other sources of information

Historically, Grey Partridge was common and widespread throughout mainland Scotland and was released onto various islands with limited and mixed success (Parish 2007). In some parts of the current distribution (Fig. A), its presence in some areas will have been supplemented by, or even be the result of, the release of captive-bred birds.

British, Irish and European trends

Declines in the range and abundance of breeding Grey Partridge have also occurred through the rest of Britain and Ireland. Contraction of occupied range (as measured by presence in 10-km squares) of 39% in Britain and 95% in Ireland were reported between 1970 and 2010 with declines of relative abundance of -0.47 in Britain (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013). In Ireland, the population is thought to have dropped to as few as 20 birds in recent years.

A European trend derived from 11 countries in west and central Europe, suggests a decline in abundance of -94% between 1980 and 2013, with most of decline having occurred before the mid-1990s (Fig. F, <http://www.ebcc.info/index.php?ID=587>).

BOCC4 status = **Red**

Birds Directive status = Annex 2.1

BirdLife EU status = LC

IUCN global status = LC

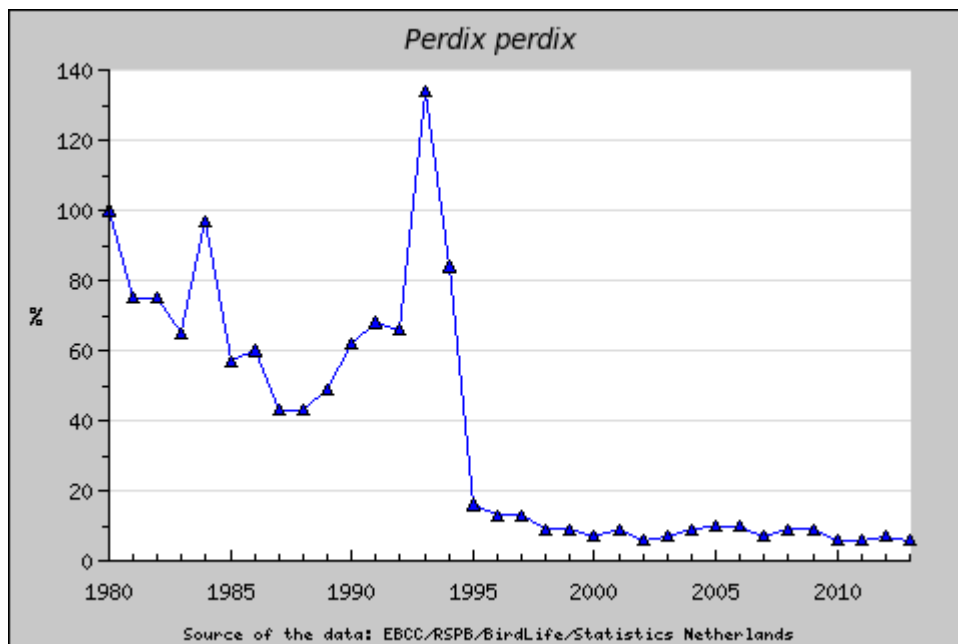


Fig. F. Changes in the abundance of breeding Grey Partridge in Europe between 1980 and 2013
(Pan European Common Bird Monitoring Scheme: <http://www.ebcc.info/pecbm.html>).

At both European and EU27 scales this species has an extremely large range, and hence does not approach the thresholds for Vulnerable under the range size criterion (Extent of Occurrence 10% in ten years or three generations, or with a specified population structure). Despite the fact that the population trend appears to be decreasing, the decline is not believed to be sufficiently rapid to approach the thresholds for Vulnerable under the population trend criterion (30% decline over ten years or three generations). For these reasons the species is evaluated as Least Concern within both Europe and the EU27 (<http://www.birdlife.org/datazone/info/euroredlist>).



LAPWING

Vanellus vanellus

Distribution and abundance

Amongst the most widespread breeding wader in Scotland, Lapwings were considered to breed in 782 10-km squares during 2008-11 (Fig. A). Highest densities were in the eastern lowlands and upland margins, the Northern and Western isles and also some of the Inner Hebrides (Fig. B). They were absent or present at low densities across many parts of the western and central Highlands and also the Galloway Hills (Fig. A).

Changes in distribution and abundance

Atlas data

Between 1970 and 2010, the breeding range of Lapwings contracted by 18% (170 10-km squares) in Scotland, with a 9% decrease since 1988-91 (Fig. C). Although complete losses have been largely restricted to the West Highlands and Galloway, there has been widespread reductions in the abundance across the remainder of their breeding range (Fig. D; [Appendix S3](#)), a pattern of change that is similar to that for Curlew.

Breeding Bird Survey data

The BBS has sampled an average of 87 1-km squares in Scotland in which Lapwings have been recorded between 1994 and 2014. These show a statistically significant decline in abundance of -59% (95% confidence interval - 68% to -47%) during that 20 year period (Fig. E).

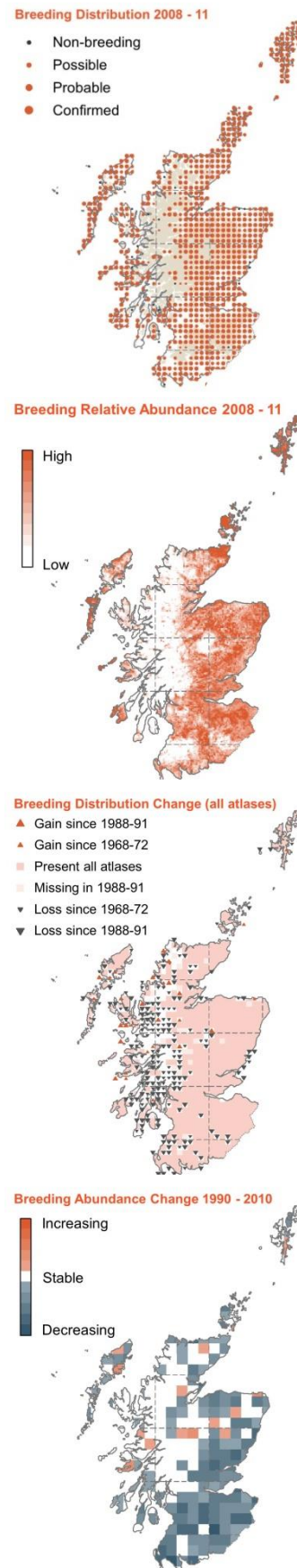


Fig. Current (A) distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Lapwing in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

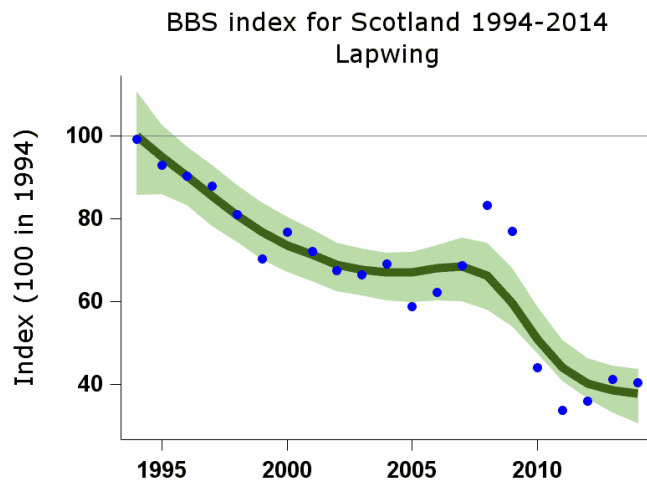


Fig. E Breeding Bird Survey trend for Lapwing 1994-2014.
 (Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Other sources of information

A general range expansion during the mid 19th Century saw colonisation of both Orkney and Shetland after which there appears to be little evidence of major changes until the mid-20th century (O'Brien 2007). Abandonment of some areas in the west Highlands appear to have occurred in before some of the population declines in the remainder of their range was detected (e.g. Galbraith 1984, O'Brien 1996).

Other local studies provide additional evidence for a widespread decline in numbers of breeding Lapwing in Scotland. For example declines were reported in three of four upland survey areas between the 1980s and around 2000, the exception being an area in northeast Scotland (Sim *et al.* 2005) and in parts of Tayside breeding Lapwing numbers declined by almost two-thirds between 1992 and 2012 (Davies *et al.* 2014). Despite these declines some relatively high densities of breeding Lapwing do persist in some parts of Scotland (Fig. B) at least some of which are in areas of low intensity, 'traditional' land-use and a restricted suite of predators (e.g. the Uistmachair; Calladine *et al.* 2015)

British, Irish and European trends

Declines in the range and abundance of breeding Lapwing have also occurred through the rest of Britain and Ireland. Contraction of occupied range (as measured by presence in 10-km squares) of 17% in Britain and 53% in Ireland were reported between 1970 and 2010 with declines of relative abundance of -0.21 and -0.45 respectively (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013).

A decline of 55% is reported across Europe between 1980 and 2013 (Fig. F; <http://www.ebcc.info/index.php?ID=587>). This plover is classified as vulnerable in both Europe and the EU27 because it is estimated to have undergone rapid declines during the past three generations (27 years; <http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Red**

Birds Directive status = Annex 2.2

BirdLife EU status = VU

IUCN global status = NT

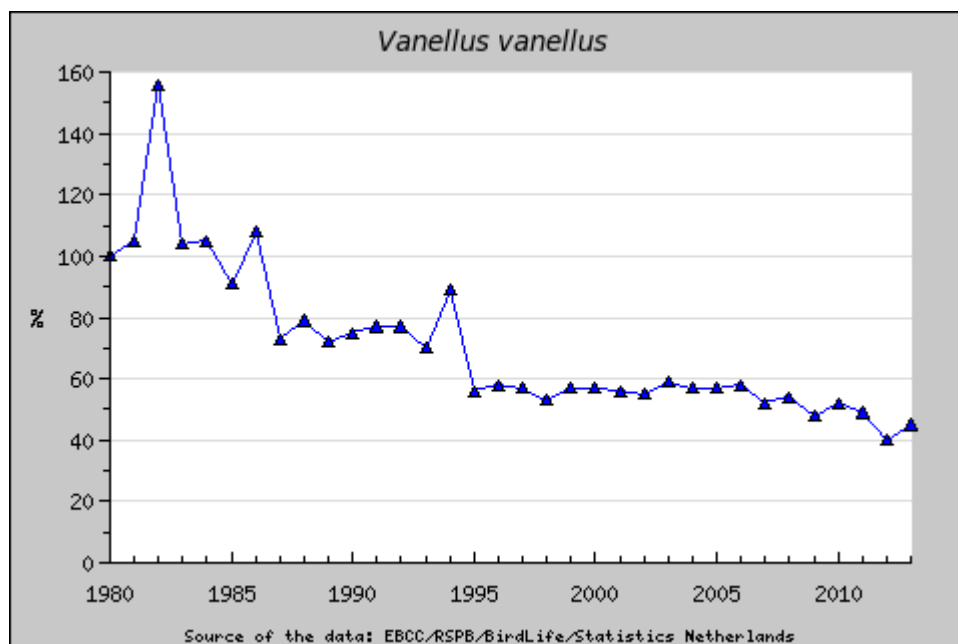


Fig. F. Changes in the abundance of breeding Lapwing across European farmland between 1980 and 2013 ([Pan European Common Bird Monitoring Scheme: http://www.ebcc.info/pecbm.html](http://www.ebcc.info/pecbm.html)).



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OYSTERCATCHER

Haematopus ostralegus

Distribution and abundance

A very widespread species, the Oystercatcher breeds in nearly all parts of Scotland (Fig. A). The lowest densities (including the few unoccupied 10-km squares) were in the areas with greatest amount of high altitude ground, though they do occupy glens that penetrate even the most mountainous areas (Fig. B). Breeding was considered to occur in 1016 10-km squares during 2008-11 (Fig. A).

Changes in distribution and abundance

Atlas data

Between 1970 and 2010, the breeding range of Oystercatcher changed relatively little with a net decrease of just 2% (22 10-km squares) in Scotland (Fig. C). However, there has been a general decline in abundance between 1990 and 2010, which was most marked in the east and south (Fig. D). In contrast, some populations increased, particularly those in the Hebrides and some parts of the Highlands (Fig. D; [Appendix S3](#)).

Breeding Bird Survey data

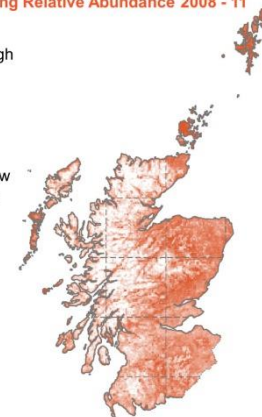
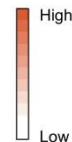
The BBS has sampled an average of 132 1-km squares in Scotland in which Oystercatchers have been recorded between 1994 and 2014. These indicate a statistically significant decline in abundance of 21% (95% confidence interval -41% to -14%) during that 20 year period (Fig. E).

Breeding Distribution 2008 - 11

- Non-breeding
- Possible
- Probable
- Confirmed

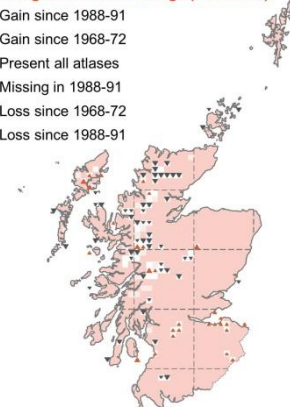


Breeding Relative Abundance 2008 - 11



Breeding Distribution Change (all atlases)

- ▲ Gain since 1988-91
- ▲ Gain since 1968-72
- Present all atlases
- Missing in 1988-91
- ▼ Loss since 1968-72
- ▼ Loss since 1988-91



Breeding Abundance Change 1990 - 2010

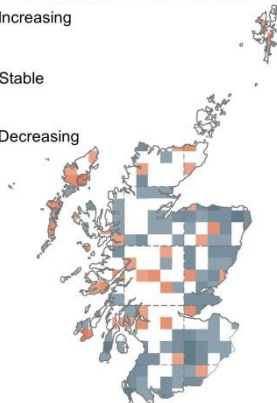
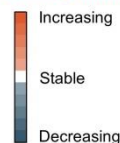


Fig. Current (A) distribution and (B) abundance, and (C & D) changes (1968-72 to 2007-11) for Oystercatcher in Scotland. BTO Mapstore (<http://app.bto.org/mapstore/>).

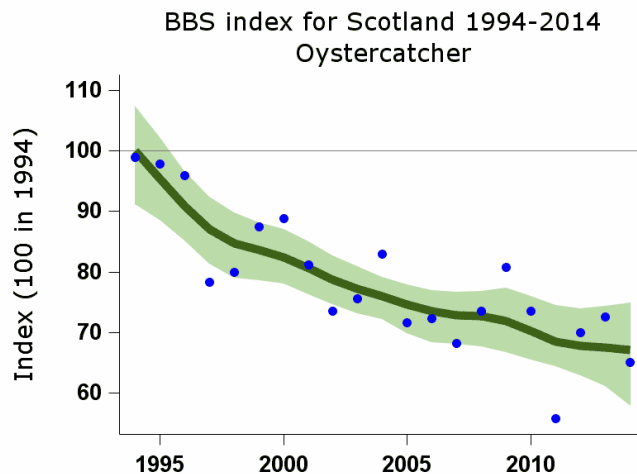


Fig. E Breeding Bird Survey trend for Oystercatcher 1994-2014.
(Source: <http://www.bto.org/volunteer-surveys/bbs/latest-results>)

Other sources of information

Formerly restricted to coastal areas, Oystercatchers started breeding inland during the 19th century. The spread continued into the late 20th century by when all but the most upland areas of Scotland were occupied (O'Brien 2007). Some local and regional studies provide further evidence for a variation in recent population trends between different parts of Scotland, for example an increase in Western Isles (Calladine *et al.* 2015) and stability or decreases in the east (Davies *et al.* 2014).

British, Irish and European trends

The range and abundance of breeding Oystercatcher has increased across the rest of Britain as a whole. A range expansion (as measured by presence in 10-km squares) of 28% in Britain was reported between 1970 and 2010 with increased relative abundance of +0.11 (an index derived from the change in the proportion of occupied tetrads within occupied 10-km squares) between 1990 and 2010 (Balmer *et al.* 2013). Much of the expansion involved a spread to inland areas of the English midlands and East Anglia, possibly a continuation of the trend that started in Scotland in the 19th century (see Section 6.2.3). In Ireland, where the species remains predominantly coastal, there was a small net decline in range of -5% between 1970 and 2010 but a small increase in relative of abundance of +0.07 between 1990 and 2010 (Balmer *et al.* 2013).

A European trend derived from the UK, Netherlands and the four Fenno-Scandinavian countries suggests a decline in abundance since the mid-1980s with a ten-year trend of -26% (2004-13) (; <http://www.ebcc.info/index.php?ID=587>). Although widespread, oystercatchers have undergone rapid declines across much of its European range and has been classified as 'Vulnerable' in both Europe and the EU27 (<http://www.birdlife.org/datazone/info/euroredlist>).

BOCC4 status = **Amber**

Birds Directive status = Annex 2.2

BirdLife EU status = VU

IUCN global status = NT

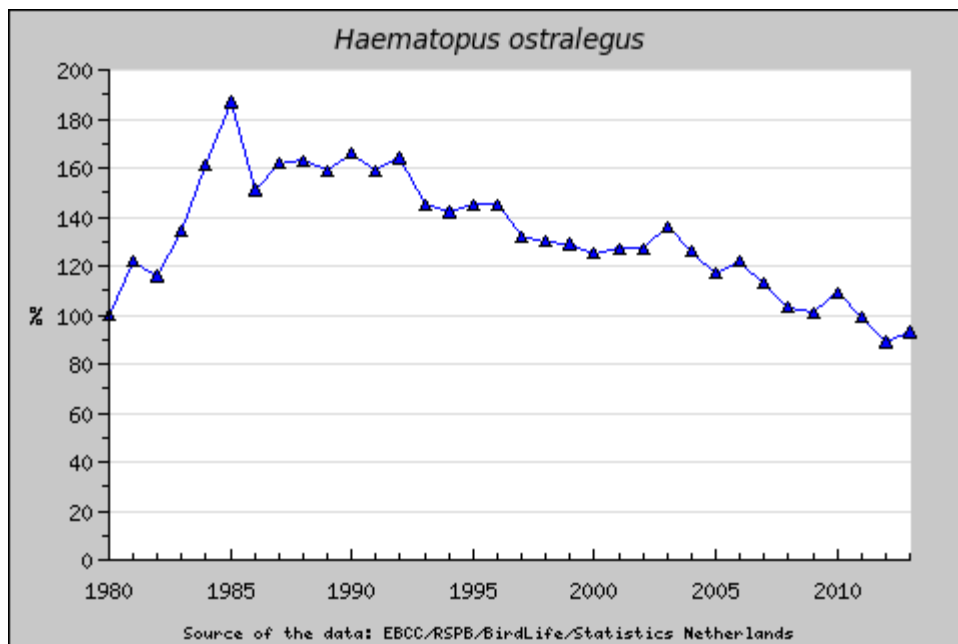


Fig. F. Changes in the abundance of breeding Oystercatcher in Europe between 1980 and 2013 (Pan European Common Bird Monitoring Scheme: <http://www.ebcc.info/pecbm.html>).

4.3 Review of population trends for wild bird prey - other breeding wild birds

In this section we summarise new population information at Scottish and regional level available from the Bird Atlas 2007-11 project (Balmer *et al.* 2013) and comparisons with the previous national atlas projects for a range of terrestrial wild bird species group. The comparable methods used in the 1988-91 and 2007-11 bird atlas projects mean that the most comprehensive information ever on Scottish breeding bird population change (both distribution and abundance) is available for the 20-year period since 1988-91. This change information forms the focus of this section

In addition to the text and summary graphs presented here, more comprehensive information is available in a series of appendices, as follows:

[Appendix S1](#) – Bird groupings and conservation status categories (for all species with a breeding range of 10 or more 10-km squares in 2007-11).

[Appendix S2](#) - Summary of distribution and national abundance change information 1968-72 to 2007-11 (for all species with a breeding range of 10 or more 10-km squares in 2007-11).

[Appendix S3](#) – Relative abundance change (20-year period 1988-91 to 2007-11) by Natural Heritage Zone of Scotland for appropriate species ([see methods](#)).

[Appendix S4](#) – Indices of relative abundance change (20-year period 1988-91 to 2007-11) for all species with a breeding range of 25 or more 10-km squares during the last two national atlases, for the whole of Scotland and for land types (Upland, Mixed and Lowland; includes differences between Upland and Lowland in abundance change; [see methods](#)).

[Appendix 11](#) – Changes in breeding distribution 1968-72 to 2007-11 (at 10-km square resolution) for predatory bird species and focal prey species

Changes in Scottish breeding bird populations since 1988-91

Of the 154 species with a breeding range of more than 25 10-km squares in the 1988-91 and 2007-11 atlases combined, overall 59 increased significantly in relative abundance over the 20-year period and 55 decreased significantly in abundance. These analyses do not include every Scottish breeding species but provide a broad overview of the balance of gains and losses over the 20-year period from 1988-91. The overall numbers of species showing significant positive or negative changes in relative abundance are summarised by bird group and land type in Figure 6, with individual species information provided in Appendix S4: Abundance change by land type.

Changes in Scottish breeding gamebird populations since 1988-91

With the exception of Common Quail, the other five native Scottish gamebirds have all declined in abundance across the land types where they occur since 1988-91, while the two species of

introduced gamebird have both increased significantly across all land types (Figure 7). The five native species have all shown decreases in relative abundance of more than 30% since 1988-91, as well as contraction of breeding range since the late 1960s. In contrast, the non-native Red-legged Partridge has shown some of the largest range and breeding abundance changes of any Scottish wild bird since 1988-91 (Appendix S2: National population change). See also detailed population trends accounts for [Black Grouse](#) and [Grey Partridge](#), and [drivers of change sections for Black Grouse and Grey Partridge](#).

Changes in Scottish breeding wader populations since 1988-91

Breeding waders as a group have fared worse than all other terrestrial bird groups in Scotland since 1988-91, with nine species showing significant declines in relative abundance (particularly in the lowlands) and only three showing significant increases (Figure 8). Most of the widespread breeding species of wader have also shown range contraction across Scotland since 1988-91 (Appendix S2: National population change). See also detailed population trends accounts for [Oystercatcher](#), [Golden Plover](#), [Lapwing](#) and [Curlew](#), and [drivers of change section for causes of population change for Oystercatcher, Golden Plover, Lapwing and Curlew](#).

Changes in Scottish breeding bird of prey populations since 1988-91

Breeding birds of prey in Scotland have shown mixed fortunes since 1988-91 (Figure 9 and [Appendix S2](#)), with some species showing significant increases in both range and relative abundance (e.g. reintroduced species and generalists like the Common Buzzard, particularly in the lowlands) but others (particularly the owls, Kestrel) showing marked declines. See also [detailed population trends accounts, as well as information on drivers of population change for birds of prey](#).

Changes in Scottish breeding waterbird populations since 1988-91

Breeding waterbirds in Scotland have shown mixed fortunes since 1988-91, with seven species showing significant increases and seven showing significant declines (Figure 10). The declining species include those more reliant on the marine environment (Common Eider, Red-breasted Merganser, Red-throated Diver) and two common birds of still and slow-flowing waters (Coot and Moorhen). Two of the most prominent increasing species are the non-native Canada Goose and Greylag Goose (the latter comprising naturalised as well as native sub-populations); these show some of the greatest increases in both range and abundance of any Scottish bird species (Appendix S2: National population change).

Changes in Scottish breeding songbird and near passerine populations since 1988-91

This group has also experienced mixed fortunes in Scotland since 1988-91, with 30 species showing significant increases and 21 showing significant declines (Figure 14 and Figure 15). Groups showing positive changes include resident woodland/more generalist species (e.g. Great-spotted

Woodpecker, Nuthatch, common tits and insectivores like Wren, Dunnock, Robin and Stonechat), the three hirundines, short-distance migrant warblers (e.g. Blackcap and Chiffchaff) and common finches (e.g. Goldfinch and Siskin). Groups and species showing marked declines include pipits and wagtails, Dipper, some migrant woodland specialists (e.g. Redstart, Wood Warbler, the two flycatchers), migrant chats and Ring Ouzel, Twite and some farmland seed-eaters (Yellowhammer and Corn Bunting). Some of the latter species have also shown major decreases in range (e.g. Wood Warbler, Ring Ouzel, both flycatchers, Redstart, Twite, Yellowhammer and Corn Bunting; Appendix S2: National population change).

Changes in Scottish breeding bird predator populations since 1988-91

For convenience, these changes are summarised in Figure 16 and Appendix S2: National population change. Details of [population changes and drivers of change for regular predators of wild birds](#) are provided in a previous section.

Changes in Scottish breeding populations of birds on General Licences 1-3 since 1988-91

These changes are summarised for all wild bird species on General Licences 1-3 in Figure 17 and in Appendix S2: National population change. Most of these species have shown significant increases in relative abundance or stable populations in Scotland overall since 1988-91, and some have also shown substantial range increases (e.g. Canada Goose, Magpie and Jay). The exceptions are Rook and Hooded Crow, which have shown significant declines in abundance across Scotland, and Lesser Black-backed Gull and Jackdaw, which have shown declines in the Upland land type. Details of [population changes and drivers of change for General Licence species that are regular predators of wild birds](#) are provided in a previous section.

Comparison of changes between upland and lowland land types since 1988-91

Of the 154 breeding bird species that occurred in at least 25 10-km squares during the atlas periods, 59 species showed trends in relative abundance between 1988-91 and 2007-11 that differed between the Lowland and Upland land types. For 38 of these species, the relative abundance trend was more positive in the Lowland land type, including 17 songbirds/near-passerines, four corvids, 4 waterbirds, three birds of prey and three waders. For the other 21 species, abundance change was more positive in the Upland land type, including 9 songbirds/near-passerines, six waders, three waterbirds, two birds of prey and one gamebird species (Appendix S4: Abundance change by land type).

Changes by Natural Heritage Zone of Scotland since 1988-91

For the [individual predator and focal species accounts of population change](#), changes in relative breeding abundance were calculated and discussed for biogeographical Natural Heritage Zones of Scotland (Figure 3). Where the distribution and abundance of species during the breeding season allows, these regional abundance changes are available for other species in [Appendix 11](#).

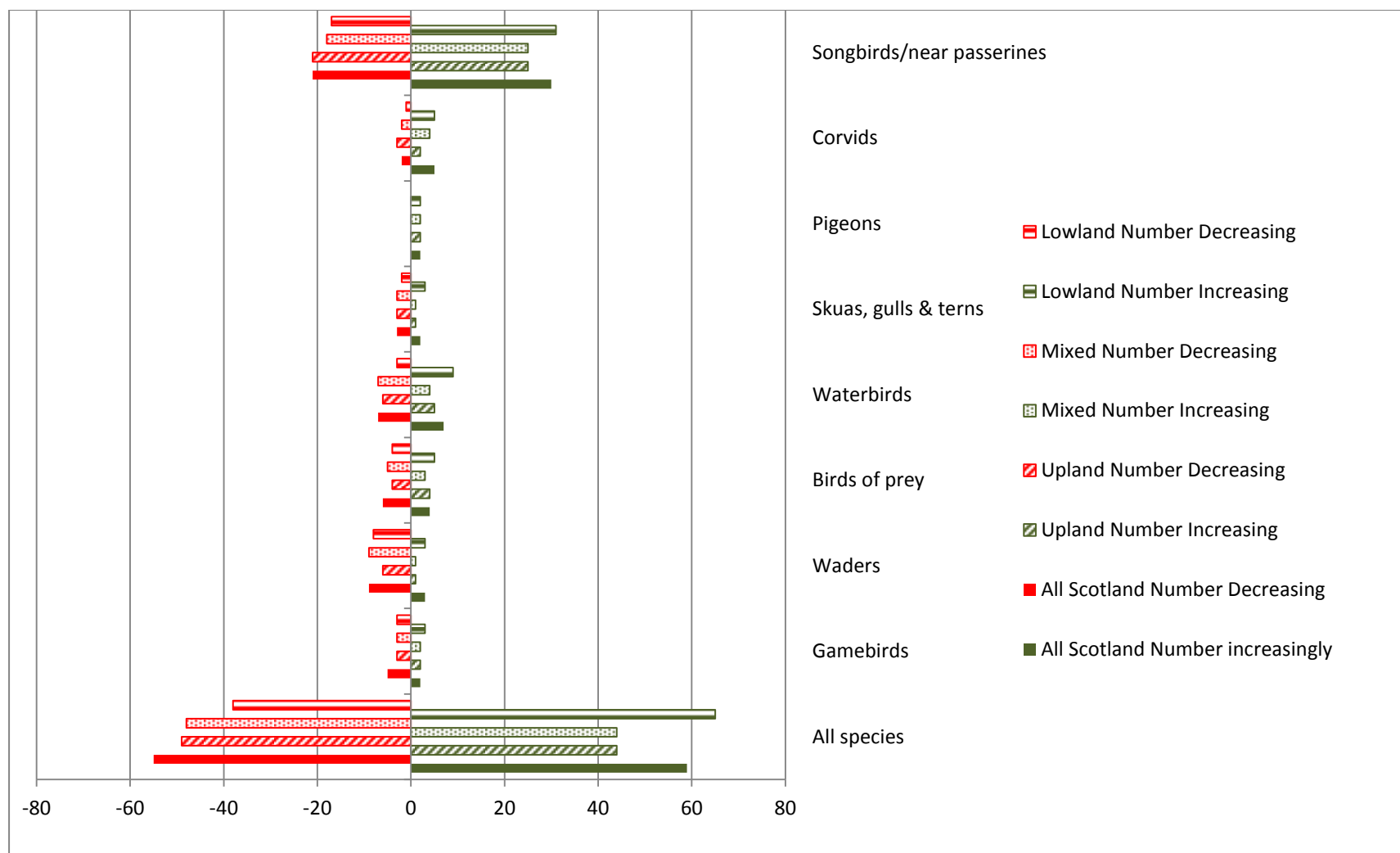


Figure 6. Numbers of species increasing or decreasing in breeding relative abundance in Scotland between the bird atlas surveys of 1988-91 (Gibbons et al. 1993) and 2007-11 (Balmer et al. 2013) by bird group and land type.

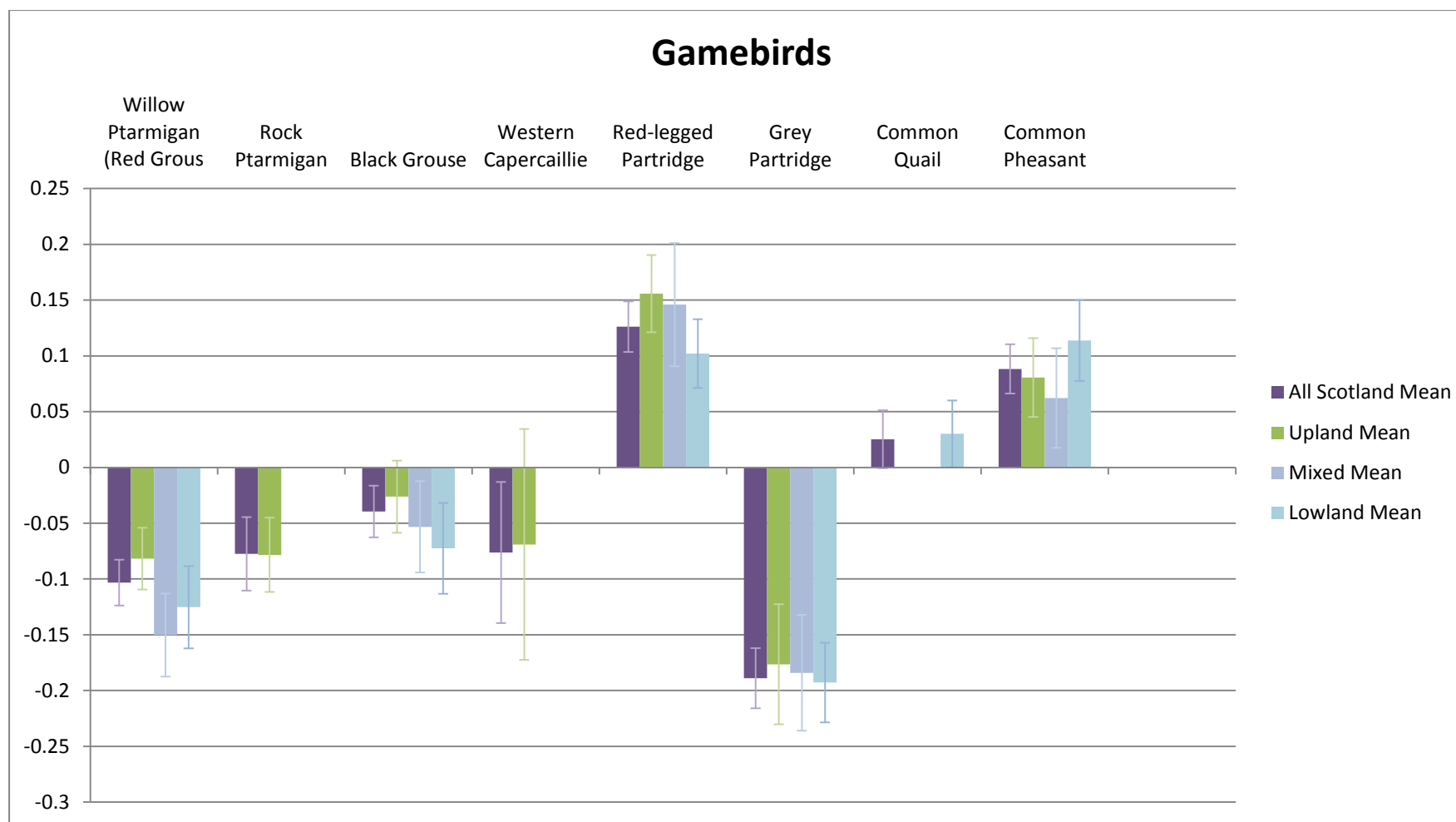


Figure 7. Change (mean index value and 95% confidence limits) in the breeding relative abundance of gamebirds in Scotland between the bird atlas surveys of 1988-91 (Gibbons et al. 1993) and 2007-11 (Balmer et al. 2013) for the entire range in Scotland and by land type.

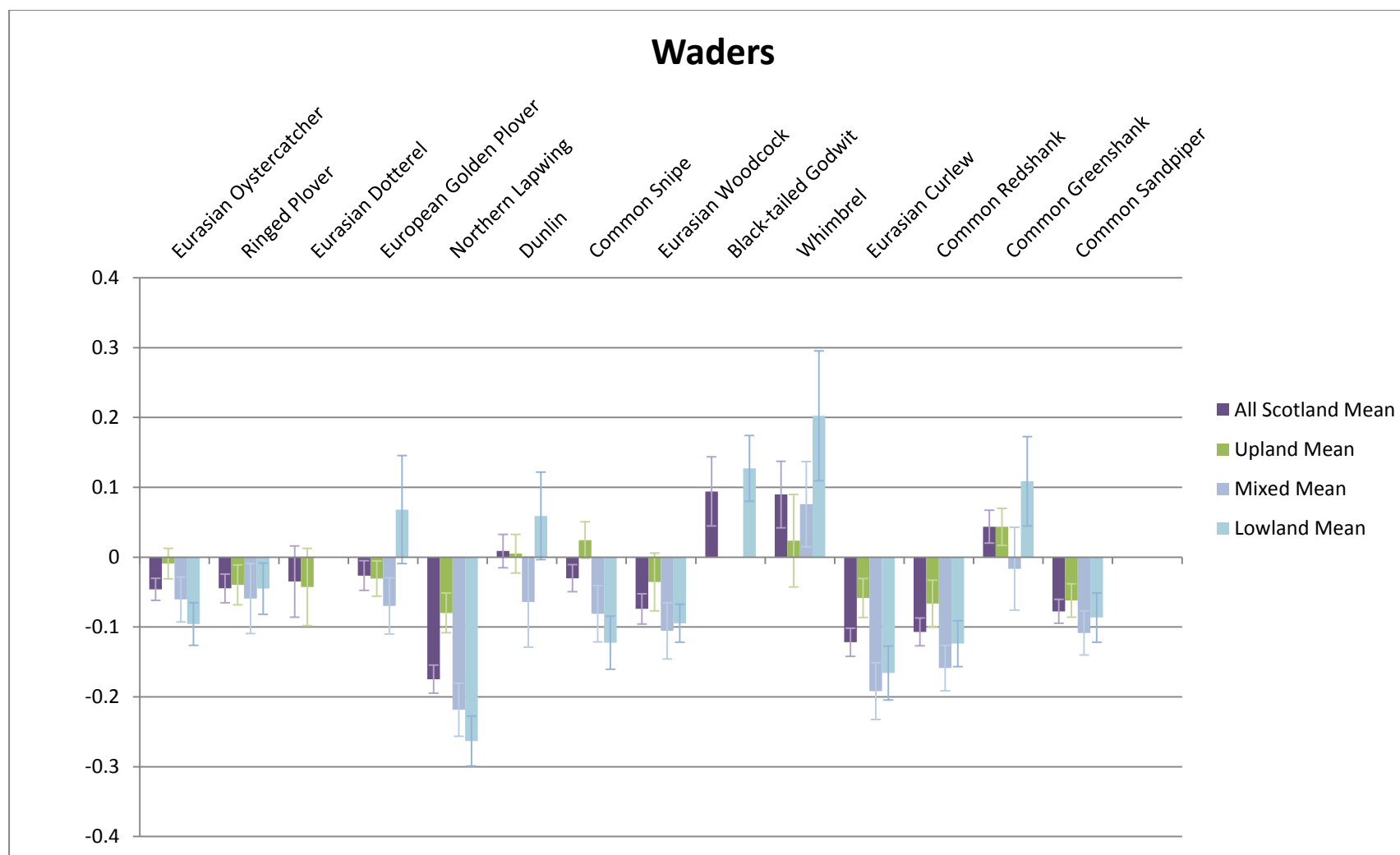


Figure 8. Change (mean index value and 95% confidence limits) in the breeding relative abundance of waders in Scotland between the bird atlas surveys of 1988-91 (Gibbons et al. 1993) and 2007-11 (Balmer et al. 2013) for the entire range in Scotland and by land type.

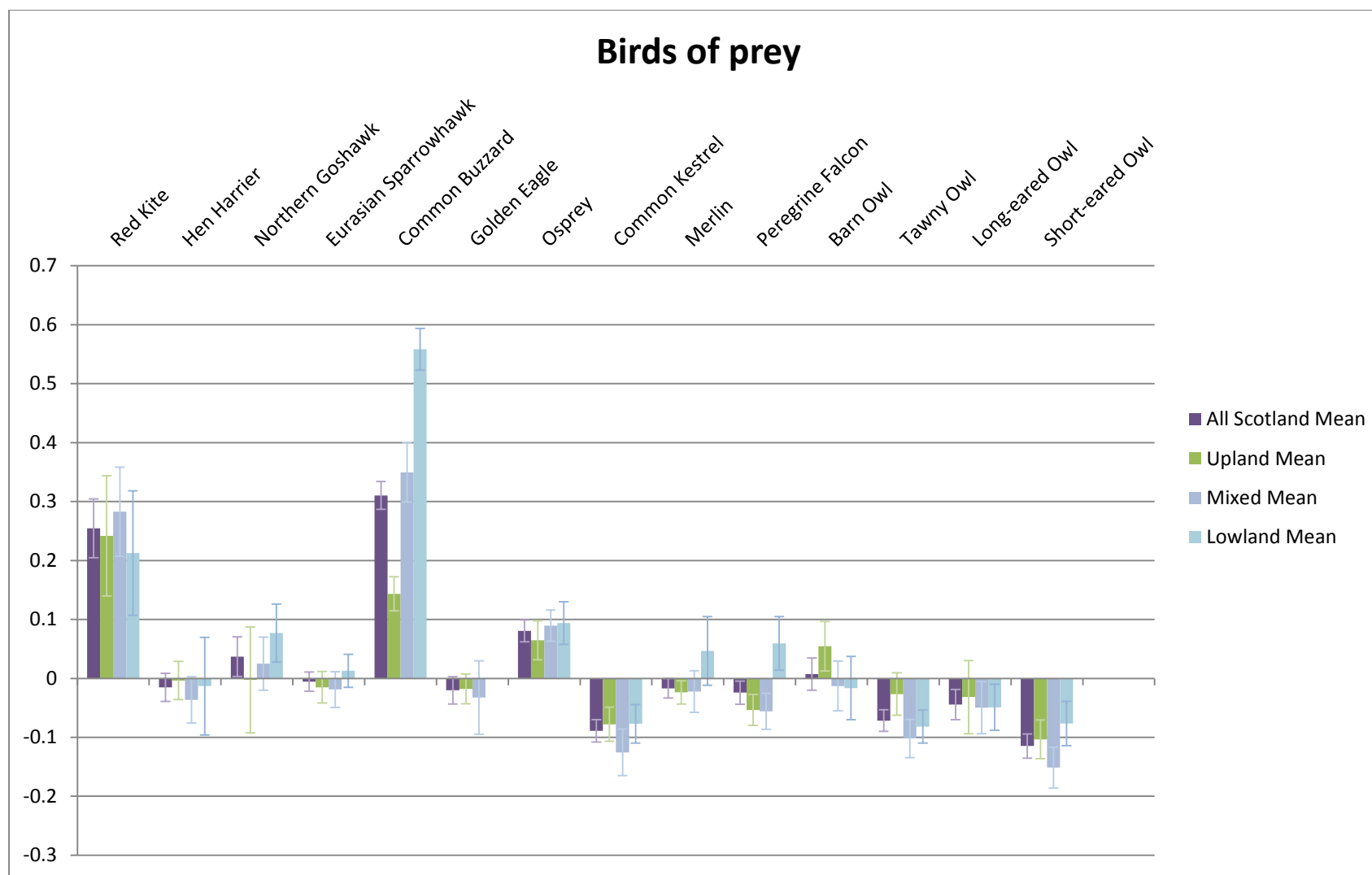


Figure 9. Change (mean index value and 95% confidence limits) in the breeding relative abundance of birds of prey in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

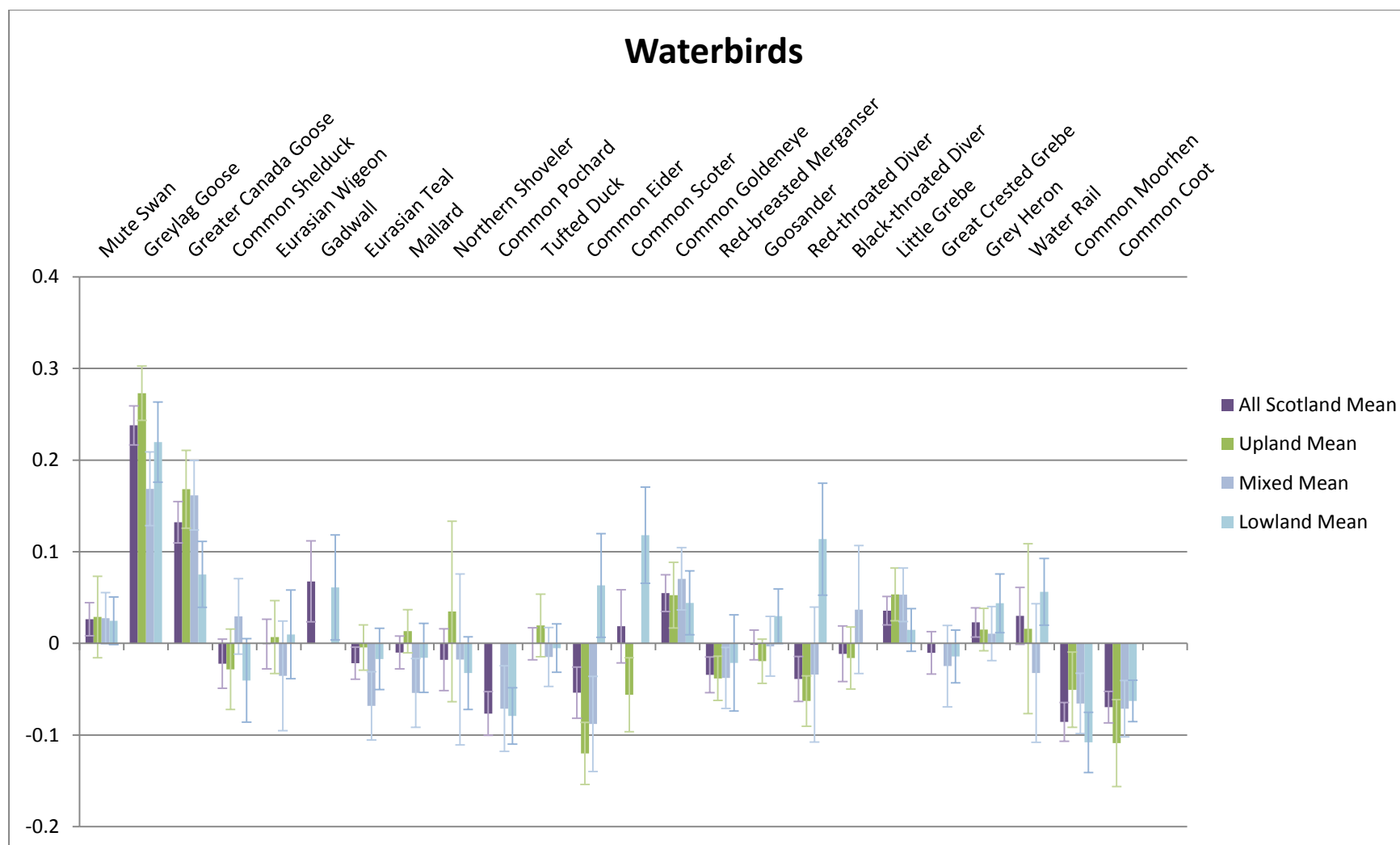


Figure 10. Change (mean index value and 95% confidence limits) in the breeding relative abundance of waterbirds in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

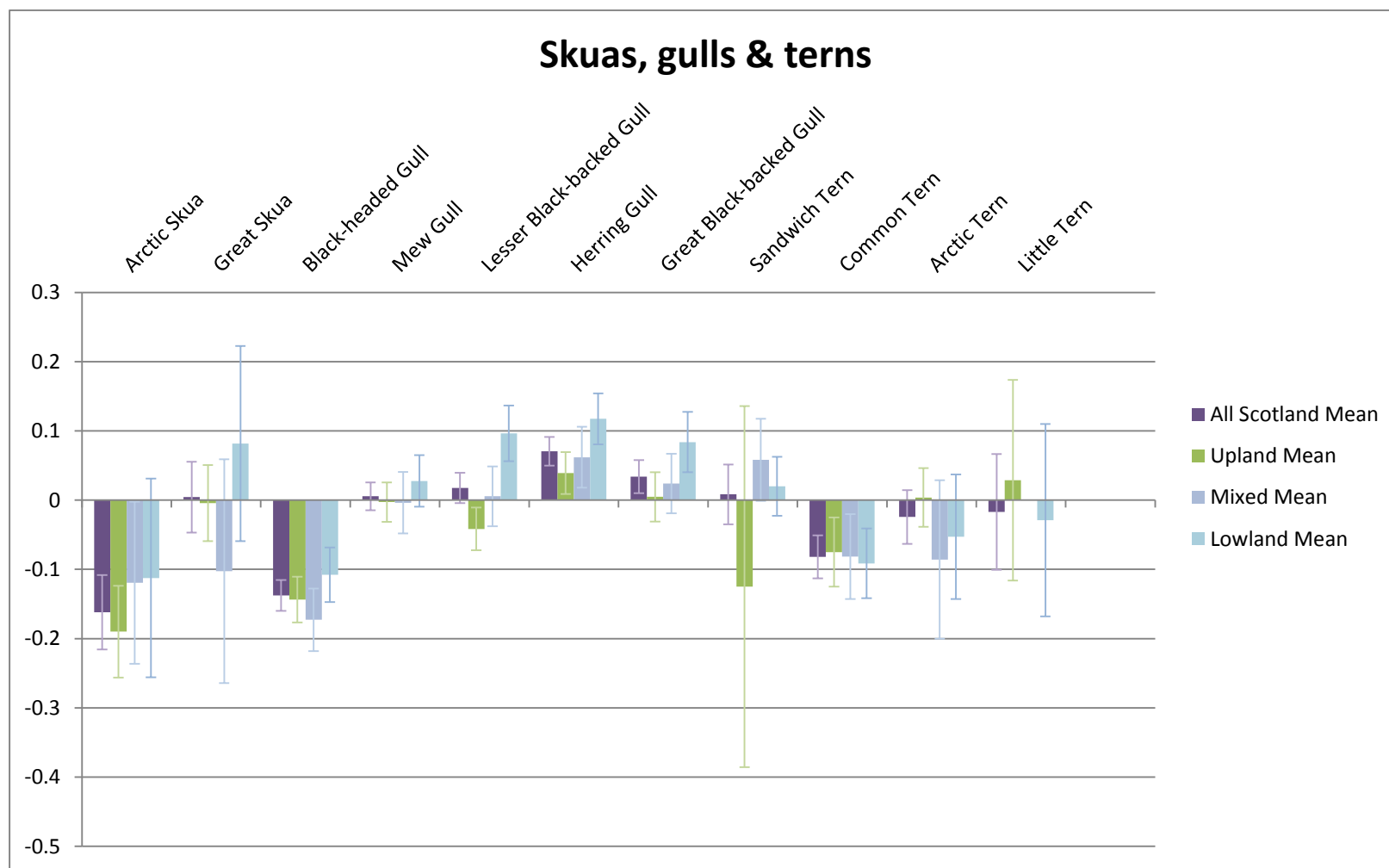


Figure 11. Change (mean index value and 95% confidence limits) in the breeding relative abundance of skuas, gulls and terns in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

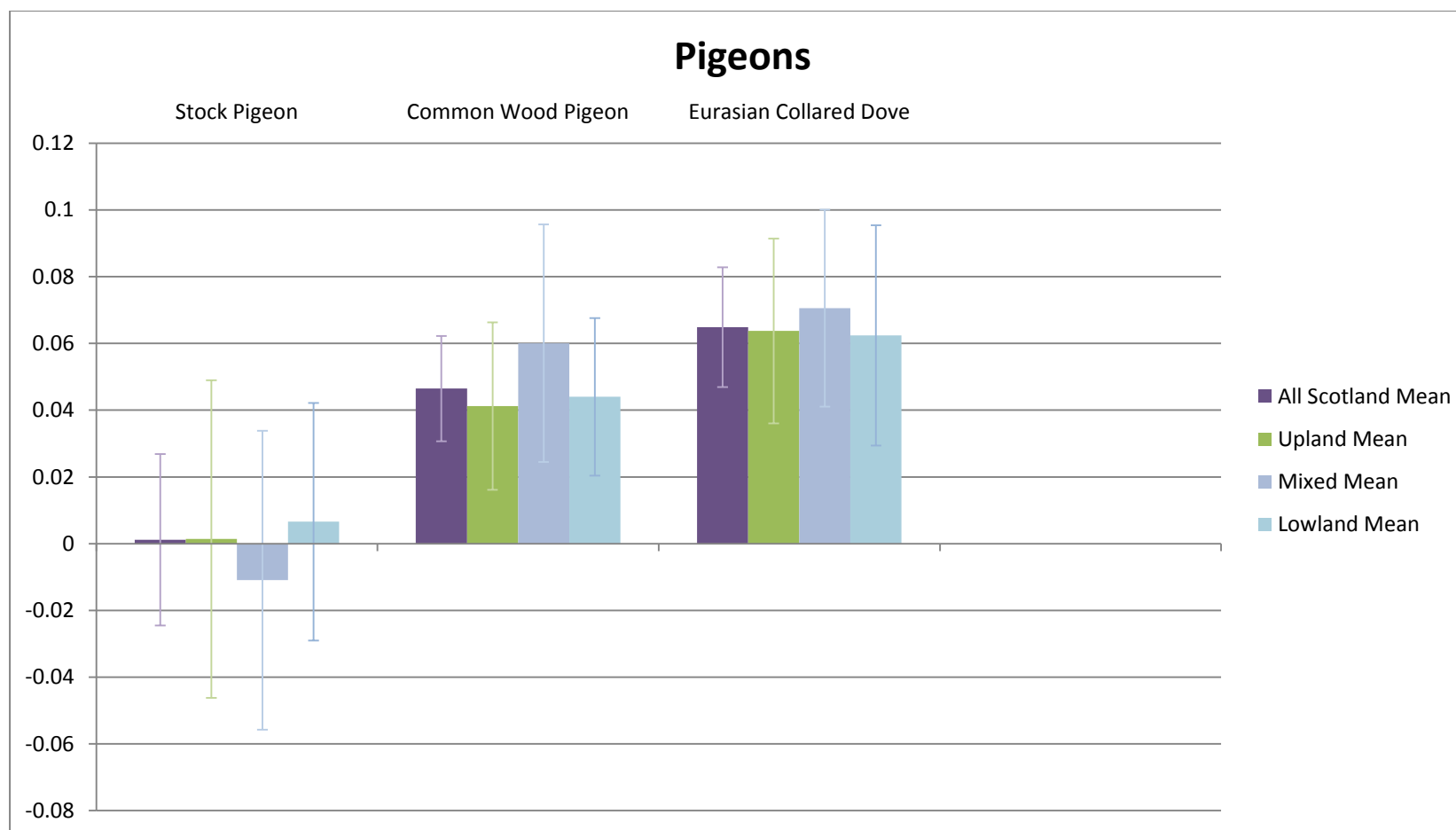


Figure 12. Change (mean index value and 95% confidence limits) in the breeding relative abundance of pigeons in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

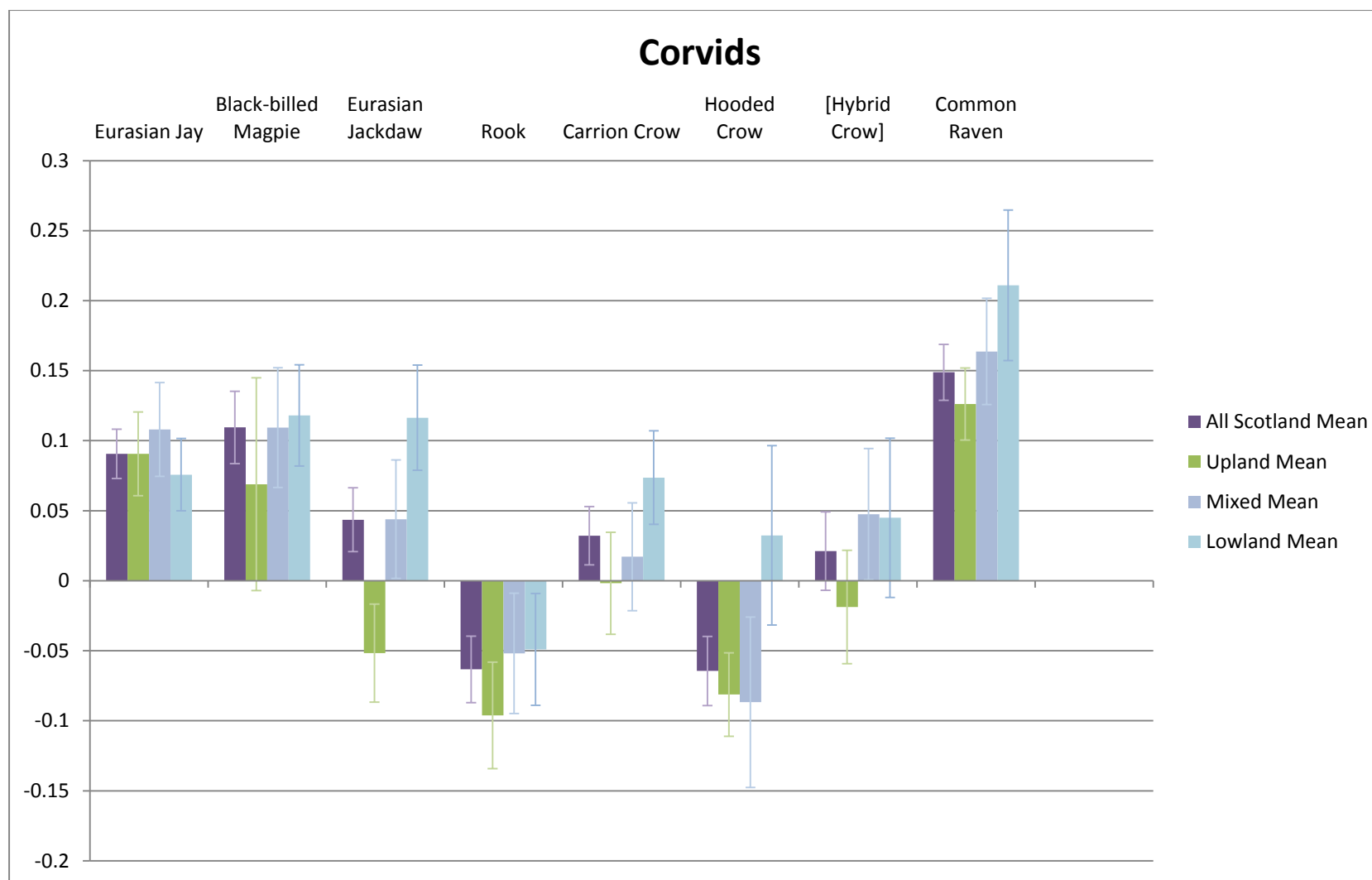


Figure 13. Change (mean index value and 95% confidence limits) in the breeding relative abundance of corvids in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

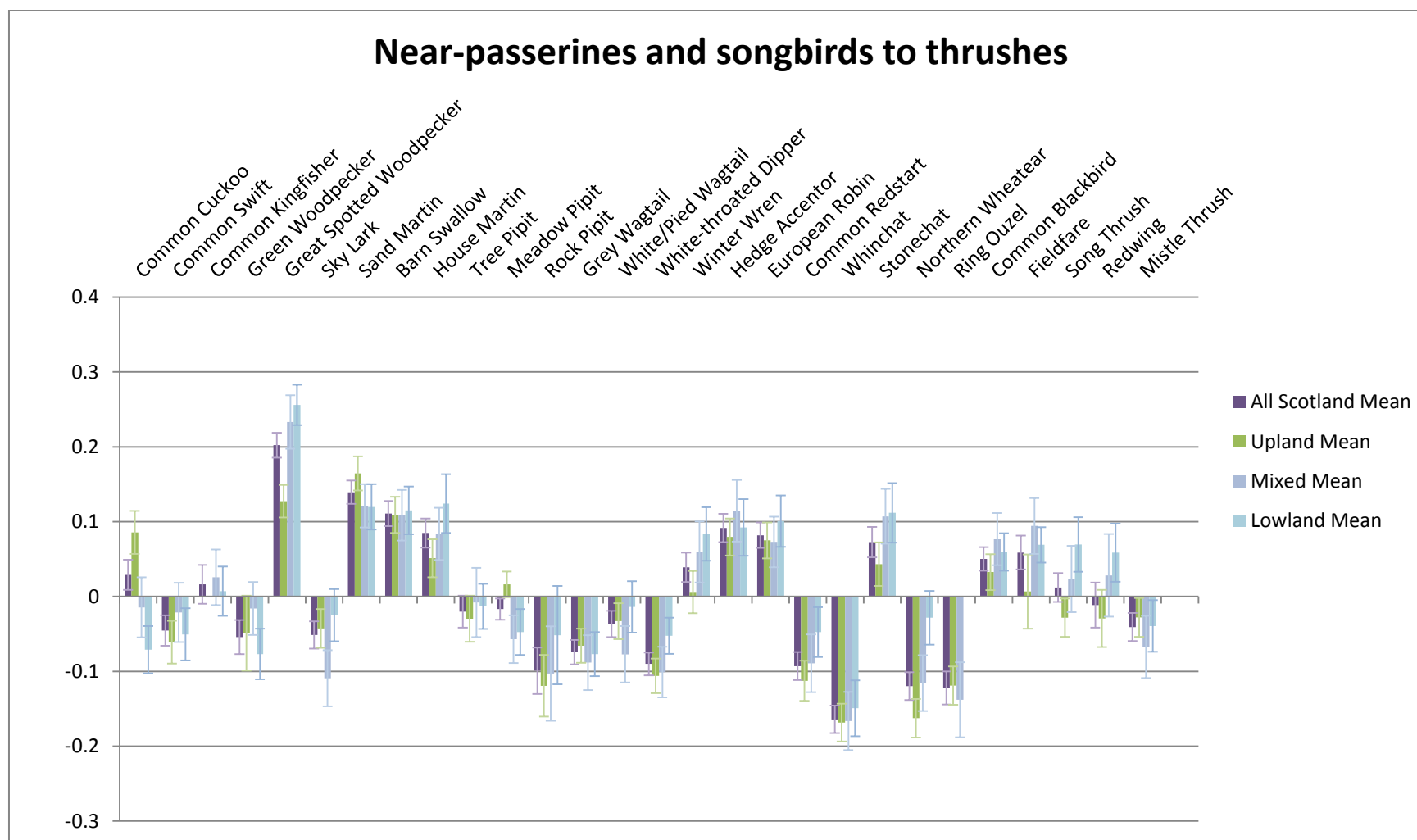


Figure 14. Change (mean index value and 95% confidence limits) in the breeding relative abundance of near=passerines and songbirds (to thrushes group) in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

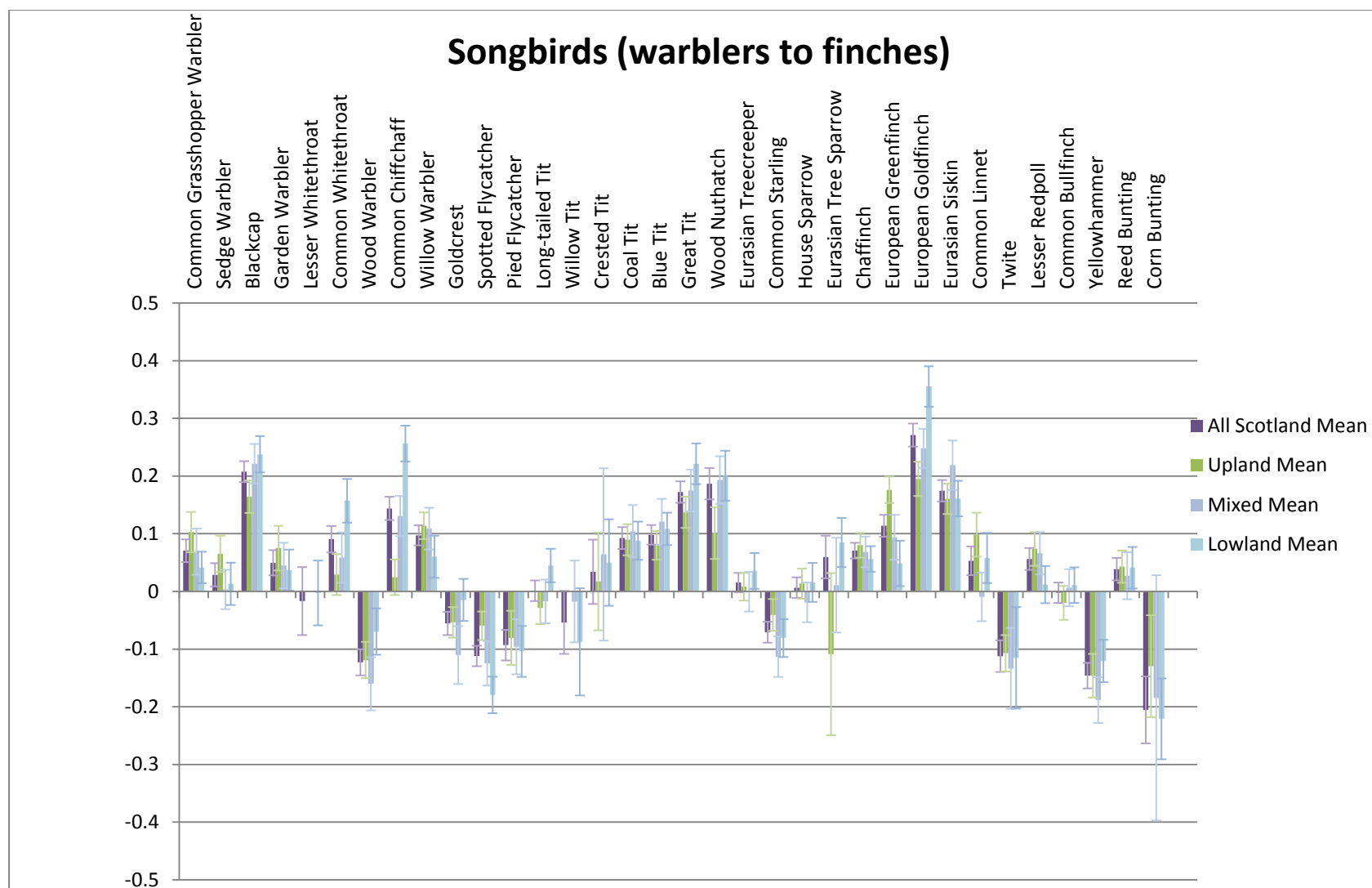


Figure 15. Change (mean index value and 95% confidence limits) in the breeding relative abundance of songbirds (from warblers to finches) in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

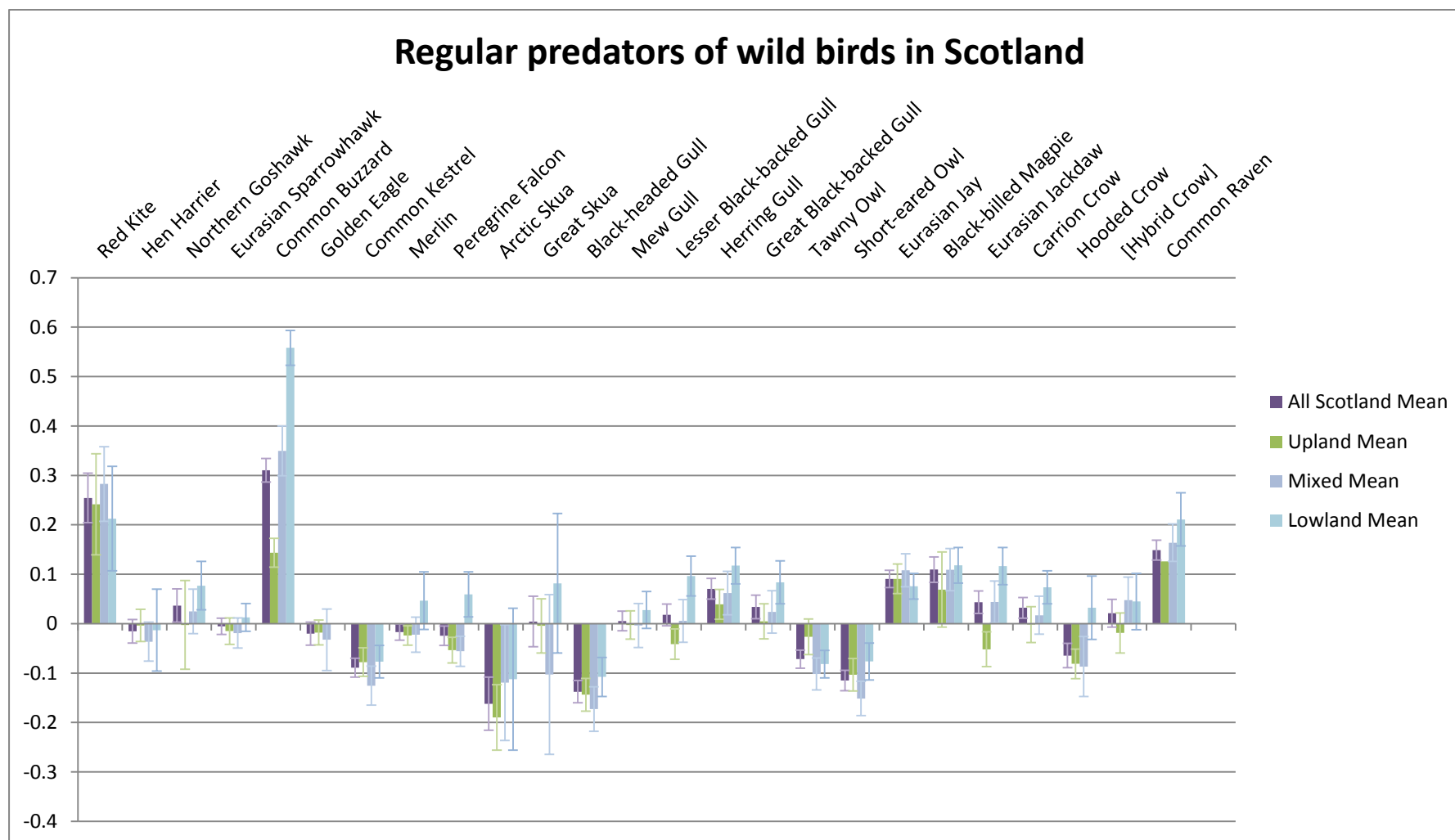


Figure 16. Change (mean index value and 95% confidence limits) in the breeding relative abundance of regular predators of wild birds in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

Species on General Licences 1-3

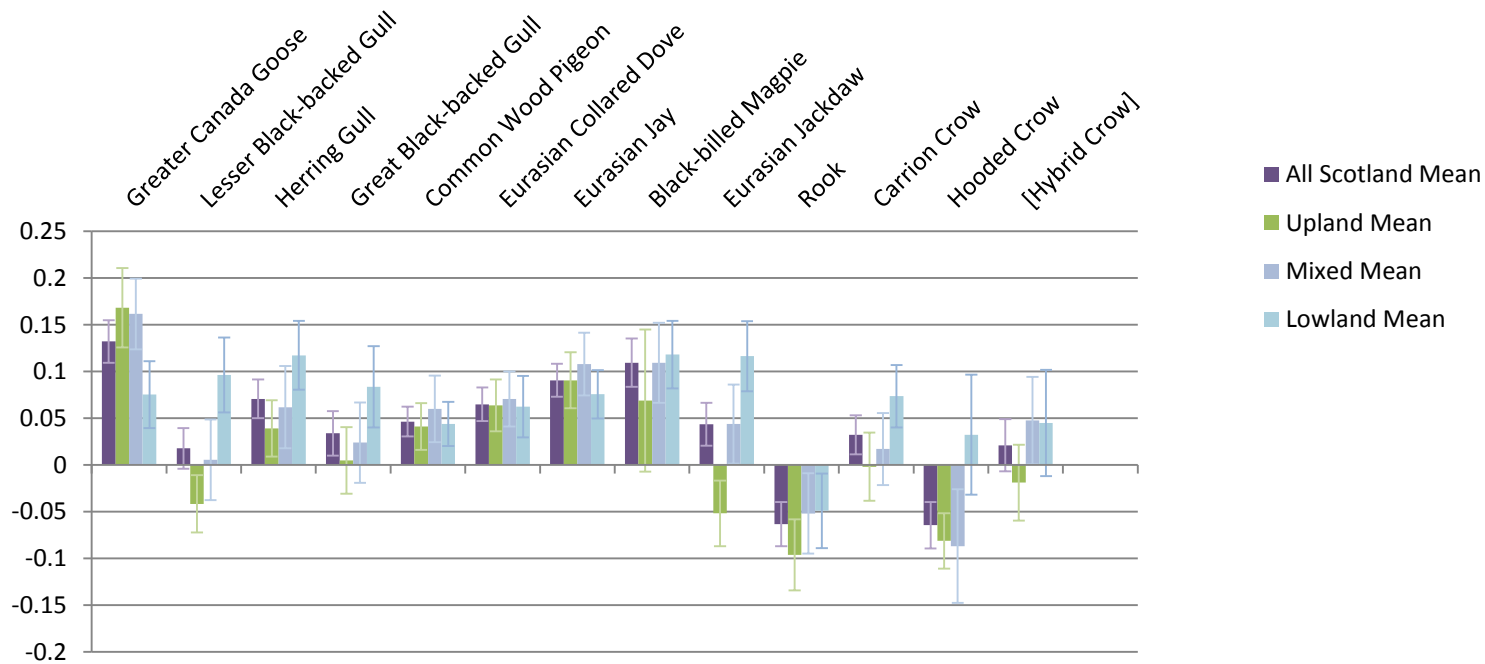


Figure 17. Change (mean index value and 95% confidence limits) in the breeding relative abundance of bird species listed on General Licences 1-3 in Scotland between the bird atlas surveys of 1988-91 (Gibbons *et al.* 1993) and 2007-11 (Balmer *et al.* 2013) for the entire range in Scotland and by land type.

4.4 Stakeholder perceptions of population trends for wild birds and their predators

4.4.1 Questionnaire results

There was broad agreement between the Local and Scientific Knowledge groups of questionnaire respondents in how they viewed changes in the population trends of the focal species (Figure 18a). Both groups perceived that the four predator species had increased, whilst the six prey species had declined. Nevertheless there were differences between the groups, with the Local Knowledge group perceiving greater increases in the four predators than the Scientific Knowledge group (2-sample Wilcoxon, $W=12828-22192$, $P<0.001$). There were also slight differences in their estimates for Golden Plover ($W=18311$, $P=0.04$), Grey Partridge ($W=19899$, $P=0.024$) and Oystercatcher ($W=29305$, $P<0.001$).

4.4.2 Workshop results

The perception that predatory species have increased overall and prey species have declined overall was supported during the workshops. However, the local level picture as described by participants appears highly complex. Many participants highlighted that some population trends may differ from overall trends at a much finer scale than was tested in the questionnaire (e.g. less than 20km²) with opinions varying depending on each participant's level of experience with individual species, their geographic location and local land management practices.

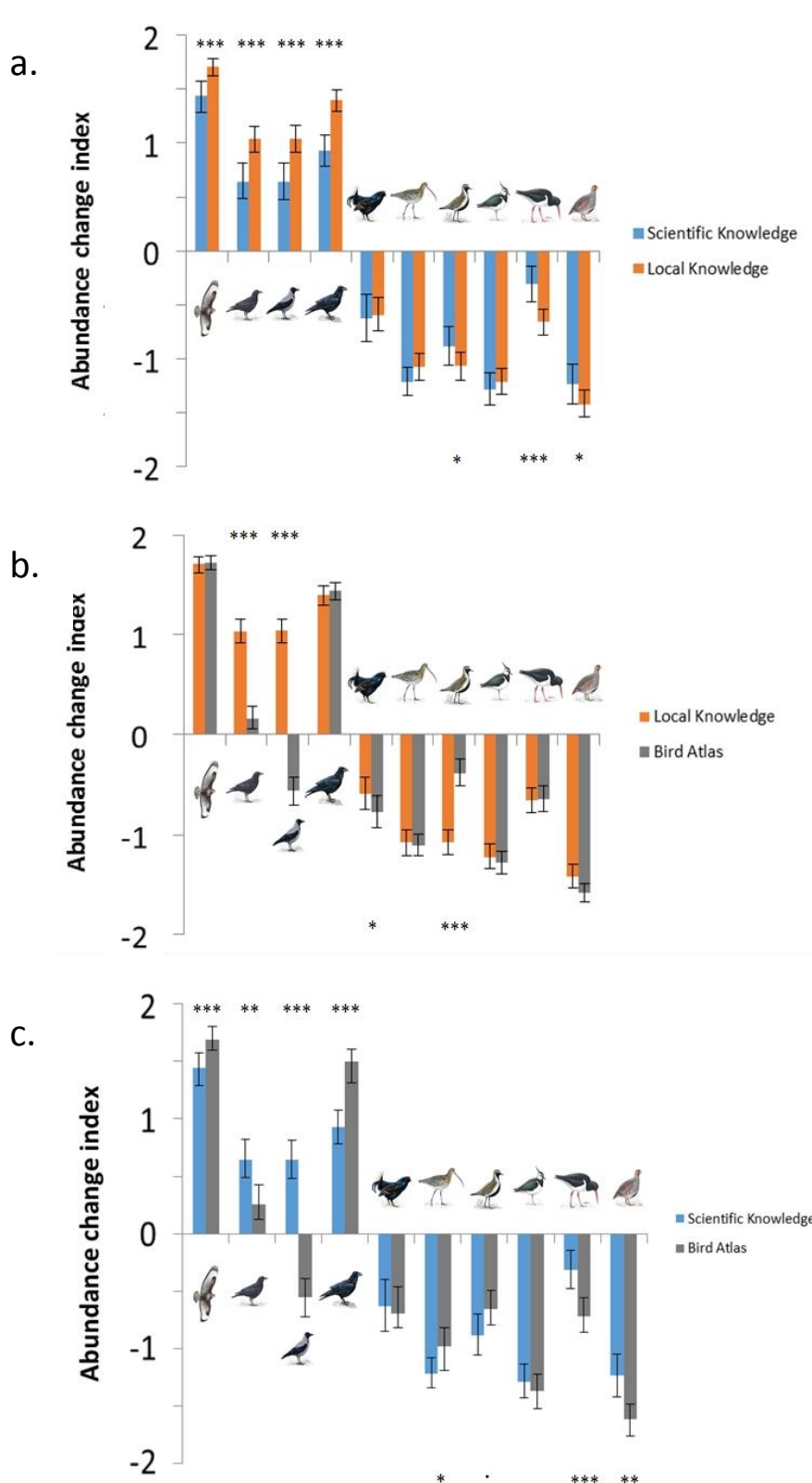


Figure 18. Average abundance change indices for 6 prey and 4 predator species over last 25 years as estimated by a) Local Knowledge and Scientific Knowledge groups, b) Local Knowledge groups and equivalent data from the Atlas data, and c) Scientific Knowledge group and Atlas data. No Atlas data were available for foxes. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

4.5 Population trends of wild birds and their predators in Scotland – comparison of stakeholder knowledge and natural science findings

4.5.1 Questionnaire results

Comparing the population abundance change estimates from the Local Knowledge group with those from the Bird Atlas, revealed differences for four species: Carrion and Hooded Crow, Raven and Golden Plover ($W > 18311$, $P < 0.04$). The Local Knowledge respondents overestimated the population change in crows and considered that the decline in Golden Plover was more severe than the Atlas data suggested (Figure 18b).

The Scientific Knowledge group estimated lower increases in Buzzard ($W = 16064$, $P < 0.001$) and Raven ($W = 15479$, $P < 0.001$) populations than suggested by the Atlas data (Figure 18c). The Atlas data for Grey Partridge ($W = 6971$, $P = 0.009$) and Oystercatcher ($W = 9890$, $P < 0.001$) suggested greater declines in these species than were estimated by the Scientific Knowledge group.

For Red Fox, there were no survey data strictly comparable to the Bird Atlas information. Both the Local and Scientific knowledge groups considered that the fox population to had shown a small increase over the last 25 years. This is broadly consistent with the best available information from game bag data for Scotland, which suggests an increase of 150% over the whole period of the NGC (1961 to 2009), but with a significant decline between 1996 and 2009.

Most (91%) of the overall variation in abundance scores between the different estimates was explained by species, with small contributions coming from Source, Knowledge, and interactions between the three variables (Table 9). There were significant differences between knowledge preference groups, and between stakeholder knowledge and Atlas estimates, but these account for little of the variation relative to species, suggesting a broad consensus between the two knowledge groups and the Atlas about how the abundances of different species have changed.

Table 9. Pseudo-r-squared values, derived from OLR models, of different combinations of species, source (atlas or stakeholder) and knowledge (local or scientific).

Overall variation in abundance change scores explained by:		
	pseudo-r-squared = $1 - (\text{residual deviance} / \text{null deviance})$	% variation
Species alone	0.210	91.1
Source alone	0.001	
Knowledge alone	0.000	
Source*Knowledge alone	0.001	0.5
Species*Source alone	0.226	98.0
Species*Knowledge alone	0.212	91.9
Full model (Species*Source*Knowledge)	0.231	
The above pseudo-r-squared values are taken from OLR (ordered logistic regression) models.		
The output for the full model (which according to AIC is the best fitting) is given in the worksheet 'OLR model'		

4.5.2 Workshop results

Workshop participants suggested several reasons why their assessments differed from those of the Atlas, many of which related to: how bird counts are conducted (e.g. time of day, duration); difficulty of assessing some species accurately due to highly mobile (e.g. corvids), non-breeding, and therefore

un-surveyed, components of some populations (e.g. Buzzard), fluctuating populations (e.g. Black Grouse, Oystercatcher); population variability at different geographic scales; and stakeholder perceptions and ecological knowledge about particular species (e.g. species that are more important to stakeholders may register more than those that are less important/well known).

4.5.3 Seminar results

Seminar participants suggested many possible explanations for the differences between stakeholder population assessments of Carrion/Hooded Crow population abundance and those based on Atlas data. The most common theme related to crow lifecycle factors which make assessing populations more challenging than for other species, including 'floating' or wandering non-breeding, non-territorial or sub-adult populations which may be more evident to stakeholders but not recorded by the Atlas methods. Carrion Crow populations were perceived to be 'filling a void' left by declining Hooded Crow populations in some areas. Increasing numbers of 'hidden populations' nesting in forestry plantations also make it difficult to accurately count individuals.

Many stakeholders cited problems specific to Atlas monitoring data on crows, many of which were due to misconceptions about the methods used to gather and interpret the data in the Atlas. Examples of perceived issues with these data included that the Atlas was not well set up to look at quantitative changes; that the Atlas assessments accounted for shrinkage of range but did not take stakeholder knowledge into account; that crows took more time to count accurately than other species so one 'quick visit' for Atlas surveys may not have been adequate; that Atlas volunteers may not have considered crows as being as high a priority for recording as some other species, and that the Atlas may gather different data from other monitors like Birdtrack). For more information on Atlas methods see section 4.1 and Balmer et al. (2013).

Problems with species identification were often mentioned, particularly the difficulty in distinguishing Carrion and Hooded Crow from other corvids, and the fact that interbreeding between the two crow species makes it difficult to accurately identify hybrids. Also nomenclature of crows is not used precisely by many stakeholders, with the names 'crow' and 'hoodie' often being used to refer to multiple species, raising the possibility that assessments of the corvids in the questionnaire may have been influenced by perceptions relating to populations of other species.

Stakeholder values and perceptions were also mentioned as possibly affecting assessments of population abundance change; because crows are licensed species they may be more in mind due to their being a target for control. Further, there may be a 'new car effect' whereby Hooded Crows are more noticeable when they move into a new area compared with species that are more familiar. This is possibly linked to a 'sink effect' whereby killing crows in managed areas results in crows moving in from surrounding areas to take advantage of available food supplies.

Socio-ecological changes also featured, i.e. crow populations may be responding locally to changes in agricultural practices in different areas, reduced sheep numbers, as well as changes in legislation and culling techniques/frequency. This was linked to stakeholder contribution in terms of managing crow populations. One suggestion aimed at helping to reduce differences between stakeholder and Atlas assessments was that different stakeholders (e.g. gamekeepers and sheep farmers) should take part in monitoring populations and reporting information about observations and trapping of

individuals. Stakeholders could also help by reporting when numbers appeared to change in situations where management had not. Some seminar respondents stated they have trust in BTO and would like to be involved in population monitoring but were not sure how to gain sufficient credibility to contribute their observations.

Finally, a few individuals suggested that differences between Atlas and stakeholder assessments should not be overstated and that it was good that there was strong convergence between local knowledge holders and scientific data over the other species because this helps to build trust among stakeholders. However, there is a need for an accurate evidence-base for crow numbers, in order to better understand their predation impacts.

5. DRIVERS OF POPULATION CHANGE OF WILD BIRDS AND THEIR PREDATORS, INCLUDING THE ROLE OF PREDATION

5.1 Natural science review of drivers of population change for wild birds and their predators

PREDATION

The impact of predation on wild bird populations can be difficult to determine as predation can be additive or compensatory, so evidence of mortality does not necessarily mean that predation is driving population declines (Newton, 1998). Predation of nests and chicks, particularly those of ground-nesting birds, is often studied but may not indicate the impact of predation if populations are limited by other factors, such as winter food availability. The populations of several declining species for which predation has been raised as an issue of concern at the local level have been shown, at larger geographic scales, to be more closely related to factors such as habitat and food supply (Aebischer and Potts, 1998; Charman et al., 2012; Lewis et al., 2007). However, because of a lack of good data on numbers and predatory activity of many predators, identifying population impacts of predation at a large scale is not straightforward. Attributing population-level effects to predation typically relies on experimental evidence, which is not available for many species. Another factor that hinders the ability of many studies to identify effects of predators is the lack of good data on their populations, resulting from a tendency of studies on predation effects to focus effort on collecting information on prey populations (Nicoll and Norris, 2010).

Further complicating the separation of predation and other factors is that the interaction between them is often important. For example, predation risk and habitat factors are often linked (Gibbons et al., 2007), as they are for Redshanks which forage in areas of high predation risk when the food availability is low (Cresswell et al., 2010). Population size or trends of both predators and prey are often reported in studies relating to effects of predators on bird populations. Many studies attempt to relate variation in these variables to the effects of predation, but are often only able to do so using surrogate measures of abundance, some of which are difficult to interpret. This particularly applies to assessments of population based on numbers of animals killed by hunters or game managers. The size of 'bag' yielded by a given level of hunting or control effort typically depends on the numbers of animals available to be killed. However, comparisons of this type of information between years, places or species that fail to take into account the level of hunting and control effort expended to result in this yield should be treated with caution. Moreover, at high levels of hunting and control, numbers of animals removed can have non-trivial effects on the numbers and activities of those remaining. Farago et al. (2012) related partridge densities at different times of year with bags of foxes and corvids. Interpretation of their data is made problematic by a lack of clarity as to whether the number of predators removed (the bag) reflected the abundance of predators (as it is commonly used), or the efficiency of predator control in this area.

A very common problem in identifying which predator species have the greatest impact on a given prey population is that few published studies clearly distinguish between the effects of different predators. Many studies relate demographic parameters of prey to presence, abundance or proximity of predators, but the correlational nature of these studies does not allow causality to be

inferred from even seemingly strong relationships. The absence of an apparent relationship between predator abundance or activity and prey demographics can be equally misleading. If predation has a strong effect on prey populations, this effect could be hard to detect if applying across the range of variation included in the study. Baines et al. (2011a) assess the apparent impact of different predators on Capercaillie, concluding that Red Fox and corvid abundance were negatively related with nest success and brood size, but that there was no evidence to suggest an effect of Pine Marten on Capercaillie productivity. However, because Pine Marten abundance was negatively correlated with that of Red Fox and crows, an effect of martens may have been masked by a larger effect of these more generalist predators.

A related problem that can apply to interpretation of evidence from predator removal experiments is that a reduction in predatory activity by one species can be compensated for corresponding increases in predation by other species. This means that, even if the removed predator was having an effect, its removal may not translate straightforwardly into an increase in breeding success, survival or population size, as other predators 'step into the breach' (Bodey et al., 2009).

Intra-guild effects

Some large raptors that occur in Britain, including Golden Eagle, Eagle Owl, and Goshawk, regularly include other predatory birds and mammals in their diet (Lourenco et al., 2011). This intra-guild predation can modify the predatory influence of affected predators by changing their numbers, distribution or behaviour, and has the potential to benefit populations of the species they prey on (Palomares et al., 1995; Sergio et al., 2007, 2008). In addition to the effects of intra-guild predation, competition between predators with partly or wholly overlapping prey bases and nest-site requirements could also result in populations of different predator species interacting with and influencing one another.

Looking at responses of mammalian mesopredator populations to predation risk by Golden Eagle, Lyly et al. (2015) found little evidence that fox or marten abundance in Finland was influenced by breeding Golden Eagle density. This contrasts with the findings of Fielding et al. (2003), who looked at the distribution and behaviour of other birds of prey in relation to Golden Eagles on the island of Mull and across Scotland, and reviewed existing published studies carried out in other areas. They found evidence that several medium-sized species of raptors, including Buzzard, Raven and Peregrine, appear to avoid areas occupied by breeding Golden Eagles. The authors surmise that this avoidance is probably due to the threat of intra-guild predation, though effects of competition are also possible. They suggest that, in parts of Scotland where Golden Eagle densities may be currently suppressed by illegal killing, allowing numbers of Golden Eagles to increase might result in reduced pressure from mesopredators (including Peregrines, Ravens, Buzzards and Hen Harriers) on populations of their prey species.

In Germany, Chakarov & Krueger (2010) found that recolonisation by a top predator (Eagle Owl) coincided with a decline in the productivity of two mesopredators (Buzzard and Goshawk). However, while the density of Goshawk also declined, Buzzard density was not negatively impacted, probably because of a positive effect of release from competition for nest sites with Goshawk, which is dominant over Buzzard.

Several studies have shown that population growth of ground-nesting raptors can be directly affected by mammalian nest predators. A nest camera study by McMillan(2014) showed that Red Fox predation was the most common cause of breeding failure in Hen Harriers nesting on the Isle of Skye. Fletcher et al. (2013) found a near-significant positive relationship between predator control and the abundance of raptors, over a 9-year experimental study, though this could also have been due to positive effects of the study on prey populations.

It is likely that the impact of hedgehogs on the productivity of ground-nesting birds in the Uists is more severe than has been described elsewhere in Britain because the numbers and behaviour of hedgehogs on these islands are not constrained by other mammalian predators, particularly , as they are in many parts of the mainland (Jackson, 2007). This form of predator-release of non-native mammals on islands where they have few competitors or predators has been described for other species by Salo et al. (2007).

Ecological traps

In the extensively human-modified landscapes that dominate most of Europe, many of the cues used by birds to make choices relating to use of resources (e.g. habitat, food supply, sites for roosting or nesting) will have evolved in very different environments, and may no longer effectively discriminate between high and low resource quality. When this kind of mismatch between preferences for and value of resources contributes to population-level impacts, it is sometimes referred to as an ecological trap (Gates & Gysel 1978, Kokko & Sutherland 2001).

Ecological traps can result in a special case of source-sink dynamics, where good quality and poor quality habitats cannot be reliably distinguished by individuals. Where there is competition for preferred habitats, this can result in individual quality becoming decoupled from survival or breeding success. Predation risk is one of the factors that can contribute to this kind of situation, where birds' preferences and decisions place them at higher predation risk than they would experience if they made alternative choices. Predation-mediated mismatches in habitat preferences have been observed for Yellow Wagtail (in relation to distance of nests from field edges and tractor tracks, Gilroy et al., 2011), and Hen Harriers (in relation to landscape-scale nest site selection, Wilson et al., 2012).

Numerical and functional responses of predators

Even generalist predators like Golden Eagles in northern Sweden can have strong responses to abundance of their most important prey species (Willow Grouse and Ptarmigan) (Nystrom et al., 2006). Similarly, Millon et al. (2009) found that, despite its being even more generalist, Sparrowhawk population growth rates in northern Denmark were particularly sensitive to variation in abundance of their two main prey species (Blackbird and Skylark). Numerical responses to prey are most likely when predators have few alternative prey – in a situation where grouse are particularly important to Goshawk because of low availability of other prey, declines in Goshawk could be caused by declines in grouse (Verdal and Selas, 2010). Changes in prey abundance can also lead to functional responses in predators, described by Newton (1998) as situations in which the numbers of prey killed per individual predator are positively related to prey abundance. This pattern of response is more likely

in generalist predators that are capable of taking a wide variety of prey, and are able to change foraging strategies according to differences in availability of different prey types (e.g. Terraube et al., 2011).

Such linkages between abundances of predators and prey are likely to make the influence of predation on the prey population more regulatory, with predation levels being higher when prey is more abundant. However, the implications for relationships between prey species are quite different. A numerical response of a predator to one species of prey would mean that increased prey abundance would lead to increased predator numbers and, potentially, greater predatory impacts on alternative prey species. A functional response to numbers of a prey species would mean that increased abundance of this prey would lead to an increased focus on this prey by the predator, and correspondingly lower predatory impacts on alternative prey species. In either case, the impacts on alternative prey populations need not be regulatory (see Alternative prey section below), predation levels that are independent of prey numbers posing a far greater threat to prey populations than responses (Macdonald et al., 1999).

Prey and predator factors that can modify predation risk

Whether, and to what extent, predation has an effect on bird populations will often depend on interactions between predation risk and other factors.

Alternative prey

The influence of predation on one prey species can be modified indirectly by the response of predator population, whether functional or numeric, to demographic variation in the populations of alternative prey. Such dynamics are well studied in systems where the population growth rates of some predators are determined, in large part, by populations of their small mammal prey. In the section focussing on predation of [Black Grouse](#) we review several Fennoscandian studies (Angelstam et al., 1984; Marcstrom et al., 1988; Tornberg et al., 2013) that show how predation risk for one prey species can be affected (both positively and negatively) by numbers of another. However, this need not always be the case. Studying Pine Marten predation of Mallards and Goldeneye in the same study areas, Elmberg & Poysa (2011) found that predation risk for Goldeneye was not affected by experimentally manipulated nest densities of Mallard, and that predation risk for Mallards was not affected by predation rates of nearby Goldeneye nests.

The potential for predation by a shared predator to mediate an interaction between the populations of two prey species is greater when the two prey species are subject to different demographic constraints. The likelihood of this is particularly strong when the numbers of one prey species are not determined by natural regulatory processes, such as is the case with released gamebirds. Between 20 and 30 million pheasants are released each year in Britain (Park et al., 2008), such that in the late 20th century pheasants were estimated to comprise 30% of terrestrial bird biomass (Dolton and Brooke, 1999). The contribution of these birds to the diet of Red Fox, corvids and other mesopredators, both as live prey and as scavenged road kill, probably subsidises populations of these predators. In turn, this is likely to make numbers of these predators less responsive to the

availability of other, wild prey, with consequences for the impact of predation on these prey populations (Lees et al., 2013).

Provenance and experience of predators

The distribution of predation risk among different areas and individuals can be influenced by the familiarity of predators with the areas within which they operate. Intensive Pine Marten control within an area of Finland resulted in the fate of cavity nests at individual sites becoming much less predictable, due to lack of familiarity of newly immigrated Pine Martens with the nests within their hunting ranges (Elmberg and Poysa, 2011).

Social behaviour

Behavioural responses to predation risk can influence group size (Cresswell and Quinn, 2010) and habitat use (Cresswell et al., 2010), with potential consequences for interactions between predation risk and other factors, such as temperature and food availability, that can have important demographic consequences.

OTHER DRIVERS OF CHANGE

Climate and weather

Weather has long been acknowledged as an important determinant of population abundance in birds and there is increasing evidence that climate change is influencing population trends (Crick, 2004). Most research has focussed on the impact of climate change on the distribution and phenology of species (e.g. Both et al., 2009; Hickling et al., 2006) and more research is required on the effect of these on populations. Most climate change impacts are mediated through complex species interactions making it difficult to predict the outcome (Cahill et al., 2012).

The range of many British bird species has moved northwards and climate change was found to be a dominant driver of range changes in British birds (Bradshaw et al., 2014). This may therefore cause declines in northern and upland species while species with southerly ranges may expand into more northerly parts of Britain (Renwick et al., 2012). In general, species are not shifting their range at a rate that keeps up with increasing temperatures (Devictor et al., 2012). Populations of many resident species correlate negatively with factors associated with winter temperatures, in particular frost days and snow days (Robinson et al., 2007). The species most strongly affected by severe winter weather were ones that often feed in the ground layer of vegetation (Robinson et al., 2007). Rising winter temperatures could therefore benefit some resident species. Breeding success of a number of species also correlates positively with breeding season temperatures and negatively with rainfall (Wegge and Kesteven, 2007). Negative impacts of rising temperatures include reductions in insect food availability due to high summer temperatures (Pearce-Higgins et al., 2010, 2010) and phenological mismatch between bird food requirements and insect prey (Both et al., 2009; Pearce-Higgins et al., 2005). Phenological mismatch has been proposed as potentially particularly negative for long-distance migrants that specialise in woodlands (Both et al., 2009). Climate change could also potentially cause increases in competitors, predators and parasites for some species (Thompson et al., 2009). Davey (2012) found that specialist species declined in Britain in response to increasing

temperatures while generalists increased. However, population trends of UK farmland birds could be explained much more by farming intensity than by weather (Eglington and Pearce-Higgins, 2012).

Physiological and behavioural responses of birds to predation risk can be modified by climate change. Cresswell et al. (2009) provide evidence that Great Tit winter mass regulation responds to the balancing of risk between starvation and predation in a manner that makes the response of mass change in response to increased predation risk change from negative to positive as winter temperatures increase.

Phenological change can also impact on predation, particularly when predator and prey are both migratory. Predation risk, assessed simply as ratio of predators to prey, can be altered by when changes in timing of migration vary between different species, though a link to population numbers or demographic rates has not been established (Lehikoinen, 2011). For example, advances in Sparrowhawk autumn migration may lead to an increased predation risk for early migrating long-distance migrants and a decreased risk for late-migrating short-distance species (Lehikoinen, 2011).

Habitat and land-use

Habitat factors were very important for many species, either mediated through variation in food abundance or predation risk. Declines in farmland birds have been extensively reviewed by Newton (2004) and are linked closely to agricultural intensification, particularly increases in wheat yields (Donald et al., 2006; Eglington and Pearce-Higgins, 2012). The evidence indicates that this is due to declines in food abundance (e.g. Butler et al., 2007; Henderson et al., 2009), particularly in winter (Gillings et al., 2005b). Declines in seed-eating birds were associated with increases in herbicide use and a switch from spring-sown to autumn-sown cereals (Newton, 2004). Declines in the availability of nesting habitats may also have affected some species (Newton et al., 2004; Butler et al., 2007).

Declines in wader species have been well reviewed by Eglington (2009) and declines were attributed largely to land drainage as well as the associated intensification of grassland management, lowering food availability (Eglington, 2009). Habitat and food shortages are likely to have driven declines in other passerines (Newton, 2004). In woodlands, species specialising in scrub and understorey vegetation, and species eating seeds in summer declined more than other species on average (Fuller et al., 2005). Population abundances of Afro-Palaearctic migrants correlated most with bioclimatic zone and habitat type of wintering grounds (Ockendon et al., 2012). Having been eliminated from much of its British range by agricultural intensification, the Corncrake is now largely restricted to the Hebrides and Northern Isles, where farming tends to be more extensive. However, even in these areas, many breeding Corncrakes rely on tailored conservation to enable them to escape the effects of a well-studied ecological trap (see [section on management](#)). Many breeding Corncrakes settle in meadow habitats which, in the absence of targeted management measures, are harvested before chicks are sufficiently well-grown to escape (Green et al., 1997).

In agricultural landscapes, predation rates on artificial nests (mostly by Red Fox) can differ according to crop type (Purger et al., 2008). Some studies have found that predation rates, particularly of nest contents, are higher in fragmented than in unfragmented landscapes (Wegge et al., 2012). Land-use and intensity of management may influence levels of predator control, and so can exert influences on bird populations indirectly through their association with abundance and activity of predators.

Interactions between predation impacts and land-use are more widely recognised for some land-uses, such as forestry, than others, including agriculture. Studies investigating the impacts of agricultural change on wild bird populations have more often considered the implications of farming practices for food availability and nesting habitat (Shrubb, 2003) than the effects of farming on activities of predators.

Some habitat impacts may be caused by the effect of food availability on predation risk: low food availability may increase detectability (because of increased foraging), increase chick begging, reduce nest defence (Evans, 2004). Habitat factors such as forest edge length and sward height may also influence predation risk, especially for ground-nesting birds (Sanderson et al., 2009). However, the evidence for, and apparent importance of, habitat as a modifier of predation risk varies between studies. Further research on interactions between habitat and predation could benefit management aimed at improving the status of prey populations (Grant et al., 1999; Avery, 1989).

Non-predation animal impacts

High density grazing by sheep and cattle causes declines in many bird populations, although low intensity grazing is likely to be beneficial for many species. Grazers can contribute to declines of waders and other ground-nesting birds directly through nest trampling, as well by increasing rates of nest predation through disturbance of nesting birds (Eglington, 2009). Sheep and cattle densities were found to be important negative predictors of the abundance of UK farmland birds (Eglington and Pearce-Higgins, 2012), though this relationship might be at least partly explained by the association between livestock density and other aspects of agricultural intensification such as use of agro-chemicals and landscape diversity. Livestock can also influence predation through subsidy of predator populations by provision of prey and carrion, though this is likely more dependent on farming practices than on stocking densities per se (Fuller and Gough, 1999). Deer reduce low woody vegetation, which forms a key element of the preferred habitat for several woodland species (Fuller et al., 2005). This may cause reduced food, increased exposure to predators and a loss of nest sites (Gill and Fuller, 2007).

We found no research examining the impacts of non-native birds in Scotland on other bird populations and thus this is not covered in any sections. There was no evidence that Ring-necked Parakeets, a species invasive to England but not present in Scotland, had a negative impact on British populations of Nuthatch or other cavity nesting birds (Newson et al., 2011). There was also very little research on the impact of competition on bird populations and research has mainly focussed on competition between predators, finding some evidence of the impact of competition on predator populations (Bodey et al., 2009; Chakarov and Krueger, 2010; Dawson et al., 2011). This is covered in detail in the predation section. The only research on non-predators was conducted on Marsh Tits and found no evidence of a negative effect of competition (Siriwardena, 2006). However, reviews by Fuller et al. (2005) and Newton (2013) have found evidence of interspecific competition among cavity nesters.

Disease and Parasites

The direct and indirect effects of disease on wild bird populations are often difficult to identify but has rarely been found to have a large impact on populations. In a review of causes of decline in 30 declining British birds, disease was not identified as a cause of decline in passerines, waders or birds of prey (Newton, 2004). However, impacts of disease on individual species can be severe, as illustrated by recent declines in Greenfinch numbers due to *trichomonosis* (Lawson et al., 2012; Robinson et al., 2010). Within the gamebirds, disease has been found only to reduce populations of Red Grouse in some circumstances (Newton, 2004). While disease may not be responsible for high levels of direct mortality in most species, there is evidence that it may make prey species more at risk from predation. Predation risk from Goshawks and Sparrowhawks was higher among birds with Malarial blood parasites, probably because of reduced metabolic activity required to escape predation (Moller and Nielsen, 2007). High intestinal parasite loads are likely to increase mammalian predation risk in Black Grouse and Red Grouse, possibly by increasing their scent (Hudson et al., 1992; Isomursu et al., 2008). A simulation study examined the effect of increased predation of heavily parasitized Red Grouse and concluded that low, selective predation can increase populations by reducing parasite transmission (Dobson and Hudson, 1995).

Agrochemicals

Increases in herbicide use have caused declines in seed plants and invertebrates, and contributed to the declines of many farmland birds, reviewed by Newton (2004). The indirect effects of increasing nutrient inputs and pesticides are reviewed respectively by MacDonald (2006) and Campbell (1997), and the increasing use of fertilisers has been one of the main drivers of grassland habitat change. There is also evidence that, in the past, organochlorine pesticides have severely impacted bird populations, particularly those of predatory birds (reviewed by Newton, 1998; Newton, 2004). More recent evidence for possible direct impacts of agrochemicals have included mortality of predatory birds from rodenticides (Hughes et al., 2013a), and associations between declines of insectivorous birds with neonicotinoids (Hallmann et al., 2014).

There is wide ranging evidence for declines in invertebrate abundance as a result of insecticide and herbicides use which, along with chemically induced changes to vegetation structure and diversity, have led to declines in bird populations (Campbell et al., 1997; Hart et al., 2006; Henderson et al., 2009; Millot et al., 2015a; Newton, 2004b; Potts, 2012; Sotherton et al., 2014). Fertilisation increases sward density and allows grazing densities to be increased which causes increased trampling risk (MacDonald, 2006). Dense sward may also reduce the availability of soil invertebrates. Fertilisation also allows changes in cropping regimes which may reduce food resources, and increase silage cutting which has particularly negative impacts on many farmland bird species due to a reduction in invertebrate food, seed food and an increased risk of nest destruction in farming operations (MacDonald, 2006). In Sweden, there was no clear evidence of a link between regional variation in declines of farmland birds with variation in the use of pesticides and fertilisers (Wretenberg et al., 2006), but overall declines of several species still closely followed trends of agricultural intensification, including use of agrochemicals (Wretenberg et al., 2007).

Other impacts of agrochemicals have been linked to contaminants associated with sheep farming in the eggs of riparian species, in particular Dippers (Eglington, 2009), but eutrophication from

agricultural run-off can also have positive effects on birds. Increases in phosphorus in inland Lochs has been linked with increases in breeding success of Slavonian Grebes (Brooks et al., 2012), and Lapwing abundance has been shown to be higher in areas with more agriculturally improved soils (McCallum et al., 2015).

Other human impacts

Other factors relating to human activities that could affect bird populations in Scotland include direct mortality from farming operations, recreational disturbance; disturbance and collision risks from roads, fences, windfarms and ski infrastructure; hunting; illegal killing and changes in pollution levels.

Most research into the impact of farming operations on birds has examined the mortality of eggs and chicks, without identifying the population-level impacts. Direct mortality of chicks from farming operations such as mowing was observed across a range of ground-nesting species including waders, upland passerines and lowland gamebirds (Bro et al., 2006; Eglington, 2009; Kamp et al., 2015; Schekkerman et al., 2009; Wilson et al., 1997). In particular silage cutting was identified as being particularly destructive (MacDonald, 2006; Wilson et al., 1997a). For many of these ground-nesting species, population changes are thought to be driven primarily by variation in breeding success so these losses have the potential to drive population changes (Eglington, 2009). There was evidence that farming operations could drive population changes under some circumstances for some lowland ground-nesting passerines (Perkins et al., 2011; Strebel et al., 2015). Under some cropping regimes, farming operations can be responsible for the majority of Lapwing egg and chick mortality, an issue which is discussed in more detail in the section on Lapwing, below (Berg et al., 1992; Sheldon et al., 2007; Kamp et al., 2015). However, under most circumstances farming operations had a small impact on Lapwing productivity compared with predation (Berg et al., 1992; Wilson et al., 1997a; Bro et al., 2006; Eglington, 2009; Kamp et al., 2015).

Research indicates that disturbance by recreation, roads and ski infrastructure can influence some bird populations under some circumstances but whether these are drivers of population change for many species is unclear, and effects may be mitigated by habitat (Thiel et al., 2011). Much of the research on recreational disturbance has focussed on ground-nesting birds, a group most likely to be influenced by disturbance. A review by Showler et al. (2010) identified that recreational disturbance reduced breeding densities of ground-nesting birds while a review of nature-based recreational disturbance on birds globally found that negative effects were identified in 28 of 33 papers examined (Steven et al., 2011). However there were other indications that the impact of recreational disturbance was limited, with evidence of this for cliff-nesting birds (Showler et al., 2010), Black-tailed Godwit (Gill et al., 2001), Black Grouse (Herzog and Krueger, 2003; Baines and Richardson, 2007), Dunlin and Golden Plover (Pearce-Higgins et al. 2007b). Disturbance by roads was found to reduce breeding densities of seven of twelve farmland bird species in the Netherlands, with reductions in density of 12-56% within 100m of roads (Reijnen et al., 1996).

Much research on the impact of mortality from collisions has focussed on the impact on upland gamebird populations of collisions with fences. Mortality from collisions has been observed across a number of species (Watson, 1979; Catt et al., 1994; Moss, 2001; Warren and Baines, 2002; Baines and Andrew, 2003; Summers et al., 2010) but there was little research into the effect of these

collisions on populations except for Capercaillie. It is likely that collisions with fences reduced Capercaillie populations in the past (Catt et al., 1994) but may be less of a problem now because of fence removal and marking (Summers et al., 2004a). Effects of disturbance from ski infrastructure were found to vary between species (Watson, 1979) while mortality due to collisions with ski infrastructure and power lines has been observed across Europe in upland gamebirds (Watson, 1979; Bevanger, 1995). However, current research into impacts of collisions with ski infrastructure in Scotland is lacking.

Wind turbine collisions and disturbance may impact some species. Across a range of British upland windfarm sites, seven of 12 upland species occurred less frequently close to wind turbines, after accounting for habitat differences (Pearce-Higgins et al., 2009) and Golden Eagles have been found to change their range to avoid a windfarm site (Walker et al., 2005). However, impacts may be less significant in other habitats, as across a broad suite of farmland birds in East Anglia only Pheasants changed their distribution in response to wind turbines (Devereux et al., 2008). A review by Marques et al. (2014) identified that birds at most risk of wind turbine collision were large birds with high weights, wing and tail lengths, wing loadings and aspect ratios. They also found that the risk of collision was related to flight behaviour and that resident raptors were at greater risk than migrating raptors while migrating passerines were at a higher risk than resident passerines. There was little recent research on the frequency and population impact of birds colliding with vehicles. Fifty years ago, Hodson and Snow (Hodson and Snow, 1965) estimated that 2.5 million wild birds were killed on Britain's roads each year. Since this time, both the volume and speed of traffic, as well as the size and number of roads, has greatly increased, and it makes sense to assume that risk posed to bird populations is commensurately greater. Ramsden et al. (2006) found that traffic-caused mortality of Barn Owl, one of the few species for which the effect of road traffic has been explicitly considered, was high enough to be a likely driver of population change.

Illegal killing is considered a likely driver of change for some predators, in particular Hen Harriers, and is covered in detail in the [section](#) on population drivers of raptors and corvids. Effects of pollution associated with agricultural activities are dealt with in the [agrochemicals section](#) above. There is little recent research on the direct impacts of other forms of pollution on bird populations in Great Britain (Eglington, 2009), but a wide range of pollutants is known to have impacted birds in other parts of the world. Lead poisoning of waterfowl from the ingestion of spent gunshot is known to cause mortality across much of Europe and North America, although population impacts and impacts in the UK are unknown (Newton, 1998). Lead sinkers on fishing lines caused population declines of Mute Swans in Britain in the 1970s and 1980s but alternative materials are now used so this is no longer a population driver (Newton, 1998). No evidence was found that heavy metals affect breeding success of Curlew (Currie and Valkama, 1998). Pollutants that can impact marine birds include oil spills and plastics (Newton 1998), but these are unlikely to impact directly on most of the terrestrial bird species reviewed here. Increased water acidity from industrial pollutants can cause declines in riparian bird populations due to declines in aquatic invertebrates and reduced availability of calcium for eggs (Newton, 1998). However, in Britain rain and stream acidity are declining (Monteith et al., 2014) and there is evidence of macroinvertebrate assemblage recovery (Murphy et al., 2014).

FOCAL SPECIES – BLACK GROUSE

Black Grouse population changes were influenced more by adult survival than by reproductive success or juvenile survival in the French Alps (Caizergues and Ellison, 1997) while in Abernethy they were generally linked to variation in breeding success (Summers et al., 2010). Park et al. (2005) found that predation was widely recognised as a proximate cause of failure in Black Grouse. In a review by Newton (2004) increased stocking densities on moorland, which reduce sward height and diversity of plant populations (and, consequently, the availability of invertebrate food for chicks), were identified as the likely driver of Black Grouse declines.

Predation

Importance of different predator species

A large number of studies have considered predation in this species, generally finding that foxes, mustelids and corvids were the major nest predators, with foxes and several species of raptors (including Peregrine, Goshawk and Golden Eagle) most commonly taking adults. Incidence of bird predation on adults and chicks vary greatly from study to study, but interpretation of most studies is made difficult by lack of experimental approach, typical uncertainties around effect of tagging, prevalence of predation of viable individuals versus scavenging and predation of moribund animals, lack of information on whether mortality impacts observed were additive or not, and often lack of certainty regarding relative importance of different bird and mammal predator species. However, there is good evidence that Carrion Crow is an important egg and chick predator of Black Grouse in Scotland, with a successful programme of crow control, and consequent rates of predation (assessed primarily through artificial nest experiments) being related to local increases in Black Grouse productivity in Abernethy RSPB reserve in Inverness-shire (Summers et al., 2004a). In Fennoscandia, Goshawks are a key predator of adults (Angelstam 1986), and adults may also be taken by Pine Marten, with a study in Sweden indicating that this occurs largely during winter (Helldin, 2000).

Two studies in the UK have distinguished between predators of free-roaming Black Grouse by following the fate of radio-tagged birds. Among 70 radio-tagged birds in northern England, predated individuals were mostly taken by Stoats and raptors (Warren and Baines, 2002). Of 26 corpses that allowed an assessment of cause, eight (31%) were assigned to Stoat, two (8%) to Fox and ten (38%) to raptors. It was not possible to distinguish between different raptor species. Six other birds (22%) were lost to disease or flying into fences. Data were not provided on the ages of these birds but the lower first-year survival rate (0.46) in comparison to adults (0.72) was attributed to predation. A subsequent study of 31 radio-tagged Black Grouse found that, over three years, 10 individuals were taken by Red Fox and 18 individuals were taken by raptors (Bowker et al., 2007). Warren & Baines (2004) state that predation of clutches and chicks, particularly by Stoats, has a strong effect on populations of Black Grouse in northern England, but do not provide data to substantiate this.

Effects on productivity, survival and population size

Evidence for impacts of predators on breeding success, survival or population densities of black grouse is mixed. Park et al. (2005) found that the impact of different predators on survival and productivity varied greatly from study to study, and that interpretation of most studies was hindered by a lack of experimental approach. Typical uncertainties around the findings of these studies included the effects of tagging, the prevalence of predation of viable individuals versus scavenging and predation of moribund animals, a lack of information on whether mortality impacts observed were additive or not, and a lack of certainty regarding the relative importance of different bird and mammal predator species.

There was no effect of the presence of gamekeepers (used as a proxy for predator numbers) on either Black Grouse breeding success or population density across 20 moors in five regions of Scotland and northern England over three years (Baines, 1996). In contrast, accounting for differences between years and regions, grazing intensity had a marked effect on both breeding success and population densities; heavily grazed moors had 36% lower density of males, 44% lower density of females, and females on heavily grazed moors raised 37% fewer chicks than those on lightly grazed moors.

As of 2005, no study had directly addressed the effect of raptor predation on numbers of breeding Black Grouse in the UK. Park et al. (2005) found some evidence that predator control was associated with population trends and breeding success, but this evidence was often confounded by other factors and information regarding the relative importance of different predators is typically poor. Park et al. (2005) found predation by raptors (particularly Goshawk and – probably non-breeding – Peregrine) to be an important cause of mortality in radio-tagged chicks in several studies, but the results of these studies are difficult to interpret due to uncertainty about the effects of tagging, and possibility of biases in ease with which predation events could be assigned to different predators. A study of 31 radio-tagged Black Grouse found that all but three birds were lost to predators over the course of three years (Bowker et al., 2007). Predation rates were higher for juveniles than for adults, and breeding productivity was not high enough to sustain the observed losses to predators.

An 8-year experiment on two islands in Sweden to test the impact of Fox and Pine Marten on woodland tetronids suggested strong effects of predation on breeding success, although support for impacts on population densities was more equivocal (Marcstrom et al. 1988). Fox and marten removal was conducted on one island for four years, after which the treatment was switched. In control years 77% of hens had chicks and the average brood size was 5.52, whilst in non-control years 59% of hens had chicks and the average brood size was 3.29. It should be noted, however, that these figures represent four tetronid species combined (Capercaillie, Black Grouse, Willow Grouse and Hazel Grouse), and data for individual species is not provided. The effect of predator removal on Black Grouse lek densities during the first four years of predator removal appeared to be marginal, although densities at leks on the island with predator removal were higher than on the control island.

Summer et al. (2004a) assessed Black Grouse productivity in relation to weather, vegetation, deer numbers and predator control over a period of 11 years at Abernethy Forest in Scotland. They found that risk of predation by Carrion Crows, as assessed both by the number of breeding pairs of crows and the predation rate on artificial nests, was related to Black Grouse breeding productivity.

Declines in population size have been circumstantially related to predation through coincident increases in fox numbers (Borg, 1987). A study in the French Alps (Caizergues and Ellison, 1997) reported that predation (principally by raptors, but also by Red Fox and mustelids) was responsible for 89% of recorded over-winter adult mortality which, in turn, was more closely related to population growth rates than either productivity or juvenile survival.

Tornberg et al. (2013) found correlative evidence that the population dynamics of different forest grouse species in Finland are inter-related through predation by Goshawk. The findings of this and at least one earlier study (Tornberg, 2001) suggest that the Goshawk population responded (positively) to numbers of Black Grouse and Willow Grouse, but not Capercaillie, but that the only one of these three species of grouse to show a (negative) population response to Goshawk numbers was Capercaillie.

Prey and predator factors that can modify predation risk

Alternative prey availability could influence predation effects on Black Grouse in starkly contrasting ways. Angelstam et al. (1984) found that nest predation of Black Grouse was higher when voles were scarce, owing to greater predation by Red Fox. Tornberg et al. (2013) found a similar relationship between vole abundance and predation on Black Grouse chicks by Goshawk and Buzzards. These authors argued that the variation they observed in chick mortality as a consequence of predation was additive, and likely to exert a greater influence on productivity than other causes of chick mortality. However, changes in management of Swedish forests that led to increases in vole abundance may have been responsible for increases in fox numbers which, in turn, could have contributed directly to declines in Black Grouse populations (Borg, 1987).

The abundance of alternative prey may contribute to predators impacting upon prey populations indirectly as well as through direct predation. Tornberg et al. (2011) found evidence supporting the *predation facilitation hypothesis* proposed to explain the negative correlation between female Black Grouse in the diet of Goshawks and the density of voles in parts of Scandinavia (e.g. Widen et al., 1987). Tornberg et al. (2011) propose that whilst Stoats are seldom successful in hunting female Black Grouse, such attacks are more common when numbers of their key prey (voles), decline and this flushes incubating hens making them more vulnerable to attacks by Goshawk and other avian predators.

Evidence for positive effects of predation on prey populations

At low predation rates, modelling work by Dobson and Hudson (1995), based on Red Grouse data, has demonstrated that a positive association between parasitism and predation risk could increase grouse population growth rates by reducing the regulatory role of parasites. However, though this work is based on empirical data, the positive effect of predation has not yet been demonstrated in the field. Also, the results of the modelling indicate that at moderate or higher rates of predation, the effect of predators on population growth rates becomes negative.

Other drivers of change

Climate and weather

It is unclear what impacts climate change will have on Black Grouse populations. Black Grouse chick survival in Britain was low when June weather was cold and wet and predation (measured indirectly as a significant difference in brood size between areas with and without predator control) had a notable impact on chick survival in cold conditions but not in years when the weather was good for breeding (Baines, 1991). However, replication in this study was low, the relevant comparison being between one year of good weather and one year of bad weather. Summers et al. (2004a) found a statistical interaction between relative predation pressure from crows (assessed through the intensity of crow attacks at artificial nests) and June rainfall, indicating that Black Grouse productivity was highest in drier Junes when crow predation on artificial nests was low. In Finland asymmetric climate change, in this example spring temperatures increasing more than summer temperatures, led to increased Black Grouse chick mortality (which correlated with population sizes) because laying phenology was linked to spring temperatures so chicks were subjected to colder weather than previously (Ludwig et al., 2006). However, other authors found no link between weather and Black Grouse productivity in Finland (Tornberg et al., 2012) and in central Europe there was only a small correlation between Black Grouse population dynamics and weather (Herzog and Krueger, 2003). In a review by Malkova and Prochazka (2003) they found that Black Grouse are better adapted to cold and snowy winter weather, rather than mild and rainy ones.

Habitat

Park et al., (2005) identified habitat and land-use changes to be major drivers of Black Grouse population decline. Recent research has supported this. Black Grouse leks are most prevalent on moorland (White et al., 2013) and their decline between 1952 and 1973 in northwest Germany was linked to conversion of moorland to farmland (Ludwig et al., 2009). Within moorland, Black Grouse are particularly sensitive to vegetation structure (Immitzer et al., 2014) and productivity was high where there was good heather coverage (Warren and Baines, 2004). Some coverage of low young native pinewoods were also found to be beneficial for Black Grouse (White et al., 2013) although where they are displaying, removal of regenerating trees may increase survival by reducing predation risk. Mire restoration and exotic conifer removal was beneficial to Black Grouse (Malkova and Prochazka, 2003). In Poland Black Grouse occurred mostly in wet-forest habitats but drainage is likely to have reduced the quality of these and now they are mainly on peat bog habitats (Malkova and Prochazka, 2003). In the Alps, Black Grouse prefer pasture with Dwarf pine and Green Alder and shrub removal reduces their habitat, particularly in winter. Open woods with Birch and Rowan were noted as good Black Grouse habitats in France (Malkova and Prochazka, 2003). Forest maturation was estimated to account for 58-78% of the decline in Black Grouse in Scotland (Pearce-Higgins et al., 2007b) and is predicted to be a key driver of future declines (White et al., 2013). Breeding success of Black Grouse has been found to be negatively related to forest fragmentation by farmland, and positively related to the availability of old forest in the landscape, which is reduced by clear-cutting (Kurki and Linden, 1995). The authors of this study suggest that this may be due to increased predation by generalist predators in fragmented landscapes.

Disease and parasites

In northern England disease was found to be responsible for very few adult Black Grouse deaths (Warren and Baines, 2002). However, Black Grouse with high intestinal parasite loads were more easily found by trained dogs than ones without intestinal parasites, indicating that parasites are likely to increase mammalian predation risk (Isomursu et al., 2008). This finding is supported by more experimental studies on Red Grouse that confirmed a link between parasitism and susceptibility to predation (Hudson et al., 1992). However, the consequences of this interaction at a population level could depend on the fitness and population-level consequences of parasitism, and the prevalence of predation.

Non-predation animal impacts

Black Grouse populations were maximised by moderate grazing (Immitzer et al., 2014) and some declines have been attributed to increased moorland stocking densities (Newton, 2004). High grazing intensity reduced sward height and supported many fewer invertebrates and Black Grouse (Baines, 1996) and a reduction in grazing in northern England was associated with increasing populations and breeding success in Black Grouse (Calladine et al., 2002). A cessation of grazing was found to temporarily increase Black Grouse populations but the benefits disappeared after 5-7 years, probably because sward height became too high (Warren et al., 2003). Despite much evidence that Black Grouse productivity and populations were affected by sheep densities, Black Grouse productivity was not found to vary with deer density by Summers et al. (2004b) but was found to be negatively correlate with deer populations in a review by Malkova and Prochazka (2003).

Other human impacts

Disturbance was found to reduce Black Grouse populations in the Alps around ski infrastructure (Patthey et al., 2008; Braunisch et al., 2011) and hiking trails (Immitzer et al., 2014) and Black Grouse leks up to 500m away from wind turbines under construction had an increased chance of relocating (Zwart et al., 2015). However, experimental evidence from the Peak district found no effect of recreational disturbance on the fecundity or survival of Black Grouse (Baines & Richardson, 2007). The impact of disturbance was identified as being minimal compared to the effect of habitat structure in influencing Black Grouse populations (Herzog & Krueger 2003).

Mortality of Black Grouse due to collisions with fences (Baines & Andrew, 2003; Summers et al., 2010) and power lines (Bevanger, 1995) was observed but was found to be very low compared to mortality due to predation (Warren & Baines, 2002). Marking fences particularly reduced collision rates for Black Grouse (Baines & Andrew, 2003). Black grouse productivity was not found to vary with fence length (Summers et al., 2004b).

Hunting caused 11% of Black Grouse mortality in the French Alps and population change was influenced more by adult survival than reproductive success or juvenile survival (Caizergues & Ellison, 1997).

FOCAL SPECIES - GREY PARTRIDGE

There is a close link between Grey Partridge chick survival rate and population change, which is largely driven by invertebrate availability (Aebischer and Ewald, 2004). In a review by Newton (1994) populations were also found to be linked to survival. At the time of the review by Park et al. (2005), the main cause of the ongoing decline of Grey Partridge in the UK was well-understood, being reduced productivity due to lack of insect food for chicks following the introduction and intensification of agrochemical application in the 1950s. However, both modelling work and experimental study suggested that predation could have additional impacts on breeding success, with consequences for population size and harvestable surpluses.

Predation

Importance of different predator species

In the review by Park et al. (2005), authors found that the main predators of Grey Partridge in the UK were corvids and Red Fox, with mustelids, rats and cats also contributing to predation impact. Predators of adult birds (particularly incubating hens) include Fox, Sparrowhawk and feral cat (e.g. Tapper et al. 1996; Watson et al. 2007b), while nest predators include corvids, rats, Stoats and Badgers (Tapper et al. 1996). Sparrowhawks were identified as the main predator of Grey Partridges by the Game Conservancy Trust (2005).

Effects on productivity, survival and population size

Park et al. (2005) found that, up to 2005, interpretation of existing studies was complicated by one or more of the following factors, including the study being based outside of Scotland and/or on a possibly unrepresentative area, small sample sizes, difficulty in assigning losses to particular predators, potential biases in data collected, uncertainty in number of individuals represented in prey remains, and lack of information on predator and/or prey population sizes.

Among the sources of information summarised by Park et al. (2005), the most convincing evidence of the collective impact of predation on Grey Partridge populations comes from a six year experiment to test the effects of predator control on breeding success and densities of this species (Tapper et al., 1996). Conducted in two study areas in England with similar partridge densities, each area was subjected to predator control for three years in turn, enabling large scale effects of climate to be accounted for. Predator control was effective at reducing the abundance of Red Fox, Carrion Crow and Magpie during the partridge nesting period, and resulted in an increase in several metrics contributing to breeding success (% of partridge breeding successfully, average brood size, young per pair). Furthermore, August numbers in predator-controlled areas increased by 75%, and subsequent numbers in spring increased by 36% (Tapper et al. 1996). The effect of control was also cumulative so that after three years of predator removal, there was a 2.6-fold difference in breeding density of partridge between sites with and without predator control. It is not, however, possible to disentangle the effects of the different predator species controlled during this study.

Grey Partridge chick survival rate is closely linked to population change, with several studies providing evidence for a positive effect of generalist predator control on local Grey Partridge populations (Aebischer and Ewald, 2004, 2012). Reviewing the impact of Hen Harriers on Grey Partridge in France, Bro et al. (2006) conclude that predation-induced mortality of female partridges

(by unspecified predators) during incubation may be a population driver. Grey Partridge is among four species (out of fifteen included in the study) for which predator control carried out as part of an agri-environment scheme was found have a positive effect on population trends (Bright et al., 2015).

Farago et al. (2012) described a 20-year programme in western Hungary aimed at increasing population densities of Grey Partridge and other small game species. Activities focussed primarily on predator control (including Red Fox, Badger, corvids, feral cats and dogs) and habitat improvements. Partridge densities in autumn were positively correlated with bags of foxes and corvids, whereas partridge densities in spring were better explained by bags of feral cats and dogs. However, interpretation of these relationships is hindered by uncertainty about whether predator bags vary principally according to predator population size or to effectiveness of predator control, as well as inability to discern the effects of individual predators.

Knauer et al. (2010) used long term bag records (41 years) within eight West Germany provinces to determine the sign and strength of association between Fox and several prey species including Grey Partridge, whilst controlling for variation in weather conditions. Whilst partridge populations were negatively associated with Fox densities, this was only statistically significant in one of the three alternative statistical models constructed and even here the size of the effect was extremely small (equivalent to a decrease in partridge populations of < 2% with a 10% increase in the fox population). The authors of this study suggest that the long term decline in partridge populations is primarily due to changes in agricultural landscapes over the same period, although this was not included in their analyses.

Although they did not directly measure the effect of predation on survival, Reynolds and Tapper (1995) demonstrated a likely effect of Red Fox predation by showing that a high proportion of potential breeders were removed by foxes. Similarly indirect evidence of a likely effect of Red Fox predation was provided by Panek (2013), who investigated the predation rate of Foxes on Grey Partridge during the breeding season in ten study areas across Poland. Predation rates were assessed by quantifying partridge remains at Fox dens, and a prey “removal index” was calculated by dividing the average number of remains with the density of partridges for each study area; this indicated that the proportion of Grey Partridge removed by Foxes was highest for low density partridge populations and decreased asymptotically for higher densities. Whilst this does not demonstrate a population-level impact of Fox on partridge, it does provide a mechanism whereby such predation could potentially limit the growth of low density partridge populations.

Watson et al. (2007b) showed that Grey Partridge density was negatively related to raptor density. However, raptor density was positively correlated with shooting intensity, and at least in some areas where partridges declined to extinction the numbers shot far exceeded the losses to raptors.

Prey and predator factors that can modify predation risk

Watson et al. (2007a) found that the effect of Sparrowhawk predation risk on Grey Partridge survival was reduced when covey size was large, due to a reduction in the need for vigilance leading to a change in the trade-off between predation risk and starvation risk.

Other drivers of change

Climate and weather

There was no research on the impact of climate and weather on Grey Partridges.

Habitat and land-use

The decline of Grey Partridges in Britain since the 1950s has been well studied and the drivers of decline covered in detail in Park et al. (2005). Population declines have been greatest in arable region (Chamberlain and Fuller, 2001) and were driven mainly by high chick mortality caused by reduced insect abundance following agricultural intensification, particularly the introduction of herbicides which decreases diversity of weed species (Park et al., 2005; Kuijper et al., 2009). Recent research and reviews have supported this, identifying the same factors associated with agricultural intensification that have caused a decline in food resources and nesting habitats (Kuijper et al., 2009; Aebischer and Ewald 2012; Sotherton et al., 2014). The breeding density of Grey Partridges closely correlated with the length of hedgerow available and the amount of dead grass at the base of the hedge (Rands, 1986). The presence of a grassy strip containing abundant dead grass was also found to increase Grey Partridge breeding success (Sotherton et al. 2014). There were strong relationship between chick survival, invertebrate abundance and pesticide use, particularly in cereal crops (Aebischer and Ewald, 2012). Farago et al. (2012) found a strong link between habitat diversity and Grey Partridge population density.

However, Potts & Aebischer (1995) conclude from modelling work that spring stocks of Grey Partridge are likely to have been severely depleted only when control of nest predators was relaxed, the combined demographic impact of predation and food supply being far greater than that of either factor on its own. Several studies show that either or both of increasing availability of food or controlling predators can result in population increases (Campbell et al., 1997; Ewald et al., 2012; Kuijper et al., 2009). A recent review by Sotherton et al. (2014) concludes that the most rapid population increases will be realised when predation is managed alongside habitat and food availability.

Reviews by Aebischer and Ewald (2012), Sotherton et al. (2014) and Kuijper et al. (2009) identified field enlargement, annual mowing and herbicide use as factors that reduce the quantity and quality of nesting cover and the abundance of invertebrates, all of which have led population reductions. Some of these impacts may be due to changes in predations risk: Park et al. (2005) found that effects of predators could be exacerbated by loss of nesting cover through hedgerow removal, loss of grassy field margins and changes to cropping regimes. Benton et al. (2003) state that the effect of vegetation structure on concealment from and detection of predators is one way in which farmland habitat change has impacted negatively on Grey Partridge and the provision of nest cover can reduce Sparrowhawk predation (Game Conservancy Trust, 2005). Predation risk by raptors, in particular, has been linked to habitat characteristics such as vegetation cover (Reitz & Mayot 2001). Furthermore, Panek (2013) provides some evidence, albeit circumstantial, that landscape structure could be an important mediator of predator-prey interactions, indicating that the predation rate is lower in areas with smaller fields and higher habitat heterogeneity. Some studies have suggested that partridge nest contents do not comprise an important component of the Red Fox's diet (Goszczyński, 1986). However, the tendency of agricultural intensification to result in simplified

landscapes and larger fields may have concentrated activities of both species in the same limited resources (e.g. permanent vegetation strips surrounding large fields), leading to higher encounter rates between predator and prey.

Agrochemicals

The decline in Grey Partridge is reviewed by Kuijper et al. (2009) and Potts (2012), and can be attributed to increases in agricultural intensity, in particular the increase in pesticide use. Only one out of 157 active substances in commonly used agrochemicals was found to be highly toxic to Grey Partridges (Millot et al., 2015b) and impacts are likely to be caused indirectly through reduction of invertebrates (Sotherton et al., 2014). Herbicides have also been found to be detrimental because of their negative impact on the diversity of weed species and thus invertebrates, both of which provide food (Kuijper et al., 2009; Potts, 2012). A reduction of herbicides and insecticides use, particularly in field edges, leads to increases in chick survival (Kuijper et al., 2009; Sotherton et al., 2014) and population growth rates (Newton, 2004).

Disease and parasites

Infections of the parasite *Heterakis gallinarum* were found to lower body condition in captive Grey Partridges (Tompkins et al., 1999). Examination of parasite loads in dead and ill Grey Partridges in north England indicated that 15% had levels of parasites that would result in death (Browne et al., 2006). However, population level effects are unknown. This parasite also infects Pheasants although has a lower impact on their body condition. The spread of *Heterakis gallinarum* by pheasants may have contributed to the decline of Grey Partridge (Tompkins et al., 1999).

Other human impacts

In the UK, losses to hunting was more than double losses to raptors (Watson et al., 2007c). Declines are higher in estates with gamebird releases than ones without (Aebischer and Ewald, 2004) possibly because of inadvertently being caught up in drives of released gamebirds (Watson et al., 2007b). Direct mortality of Grey Partridges due to farming operations has been observed but losses were generally small compared to mortality due to predation (Bro et al., 2006).

FOCAL SPECIES - LAPWING

In common with several other European wader species, recent population declines are due to a decline in productivity rather than adult survival (Roodbergen et al., 2012). Drivers of Lapwing populations have been reviewed extensively by Hudson (1994). Hudson (1994) concluded that the evidence indicates that Lapwing declines were largely due to low breeding success caused by habitat loss and agricultural intensification. However, unsustainable rates of Lapwing nest depredation were found in almost 60% of literature reviewed by MacDonald & Bolton (2008a). The effects of predation can be profoundly modified by habitat.

Predation

Importance of different predator species

The use of temperature loggers in nests (to determine timing of predation events) and, in some cases, video cameras indicates that predation of Lapwing eggs is attributable largely to mammals, whilst chicks are taken by both mammals and birds (e.g. Bolton et al., 2007; Eglington et al., 2008; Teunissen et al., 2008). Identification of predatory species, particularly for chicks, can be problematic but for mammals the key predators of Lapwing clutches are Foxes and at some sites small mustelids such as Stoat (e.g. Bellebaum & Bock 2009). Avian predators appear to vary greatly between sites but include Magpie, Hooded Crow, Carrion Crow, Rook, Grey Heron, Buzzard and Common Gull (Bolton et al., 2007; Hudson et al., 1994; Klimov, 1998; Teunissen et al., 2008). In central Sweden, Berg et al. (1992) found that nest losses to predation were higher in areas overlooked by trees suitable for use as perches by avian predators, implying that birds were among the more important predators. Amar et al. (2011b) report a negative relationship between Lapwing population change and corvid abundance, while Amar et al. (2010) found that Lapwing numbers were negatively (though not significantly) correlated with abundance of Ravens. Changes in the breeding abundance of Lapwing and other waders at Langholm between 1992 and 2006 were likely due to predation by generalist predators, but it is not possible to distinguish effects of corvids, Red Fox, and other predators whose populations are controlled by gamekeepers (see below). The relative importance of different predator types may vary from one year to another (e.g. Dadam et al., 2014).

Effects on productivity, survival and population size

Analysing Common Bird Census and Breeding Bird Survey datasets from England, Newson et al. (2010) found that, in the earlier CBC dataset, Lapwing population change was negatively correlated with changes of Kestrel, Buzzard and Sparrowhawk. However, no such relationship was apparent from BBS data. Also, the negative association between Lapwing and predatory birds could have arisen partly or entirely through habitat effects, with the areas supporting the high density of vole prey (important for Buzzards and Kestrels in many areas) typically being poor for Lapwings (Roos et al., 2012).

In Britain, studies looking at demographic rates of Lapwing have concluded that elements of productivity, particularly chick survival, have a greater impact on population growth of this species than either site fidelity or adult survival (Peach et al., 1994; Sharpe et al., 2008). Reviewing studies of breeding Lapwing, MacDonald & Bodey (2008a) suggest that 57.2% of the studies they reviewed reported unsustainable nest depredation rates, even discounting the effect of other potential sources of mortality. Most studies are unable to attribute the majority of chick mortality to particular causes. However, Teunissen et al. (2008) reported that 74% of 106 chick deaths where the cause was known were due to predation, with the remainder being due to drowning, starvation or hypothermia.

Some studies have looked for but found no evidence of an effect of predation on Lapwing populations. Among these was an experimental study aimed at testing the effects of Ferrets and Hooded Crows on the declining Lapwing population of Rathlin island, off the coast of Northern Ireland (Bodey et al., 2011). There was little effect of reduced predator abundance on Lapwing breeding success. Across the whole study area, at least one egg per nest survived until hatching, and

fledging success was approximately 0.7 young per pair. The cause of death could not be established for the majority of chicks, but most disappeared before the 10 days of age. There was some limited support for Raven activity being associated with chick loss, with broods further from raven territories enjoying higher survival rates. However, the model containing Raven activity was only marginally better than the next best model which contained no effect of Raven (Bodey et al., 2011). Bright et al. (2015) found little evidence for an effect of anti-predator measures undertaken as part of an agri-environment scheme, Lapwing being one of eleven species (out of fifteen included in the study) for which no such effect was detected. Pehlak & Lomus (2008) detected no difference in predation rates between inland mires and coastal meadows, despite Lapwing populations declining at different rates in these habitats.

In a well replicated 8-year cross-over experiment, Bolton et al. (2007), examined the effect of Fox and crow control on nests, breeding success and population trends in Lapwing at 11 lowland wet grasslands. Predator control was carried out over a block of four years at each site, and compared with four years without predator control. The effect of predator removal on nest survival was dependent on the background densities of Foxes and crows, with the greatest improvement in nest survival at those sites with the highest predator densities. There was no consistent effect of predator control on chick mortality but the authors noted that the subset of sites chosen for chick monitoring tended to have lower densities of predators. However, at the remaining sites, the proportion of adults with young (another measure of breeding success), doubled in years of predator control indicating that predator removal in areas with high predator densities can positively impact on breeding success. There was some evidence for improved population trends following predator removal, but it was not possible to distinguish between effects of productivity and mortality, and those of movement in and out of sites, making it hard to circumscribe the population-level effects of the experiment (Bolton et al., 2007).

In the Outer Hebrides in Scotland, where Lapwings have no native terrestrial predators, there is strong evidence for population level effects of nest predation by European Hedgehogs. Three studies on islands in the Outer Hebrides found that predation of eggs and chicks by introduced European Hedgehogs were in large part responsible for the subsequent declines in the populations of Lapwing and other wader species (Jackson, 2001; Jackson and Green, 2000; Jackson et al., 2004). In three study sites on South Uist, Lapwing densities declined by 36% over a period of 12 years, during which time Hedgehogs spread throughout much of the island (Jackson and Green, 2000). An experiment to determine a causal link between Hedgehogs and wader declines compared nest failure rates inside and outside two fenced exclosures which prevented entry to terrestrial predators (Jackson et al., 2004). For Lapwings nesting in the exclosures the chances of nest failure reduced by a factor of 2.3 (95% Confidence Intervals 1.4-3.7), and there was no evidence of a compensatory increase in predation of exclosure nests by Common Gulls, the other major nest predator on the island (Jackson et al., 2004).

Several other studies have also used exclosures to test the effect of mammalian predation on Lapwing breeding success. Malpas et al. (2013a) found that electric exclusion fences, designed to keep out relatively large mammals such as Foxes and Badgers, resulted in a three- to four-fold increase in nest survival and productivity, with the numbers of chicks fledged per pair rising from 0.23 (± 0.07 SE) to 0.79 ($+0.14/-0.13$ SE) when fences were used. Focussing on the possible benefits of fencing for chick survival, Rickenbach et al. (2011) showed that overnight estimates of survival for

chicks located within enclosures were far greater than for chicks outside enclosures. Under the (unrealistic) assumption that there was no movement of chicks between treatment areas, 24% of chicks from nests inside fences survived to fledging, whilst no chicks outside fences survived. Isaksson et al. (2007) found that Lapwing egg survival was enhanced by placing protective cages around the nest.

Numbers of breeding Lapwing on the Langholm estate in southern Scotland crashed during a period of time when game management was discontinued (Baines et al., 2008). Between the periods 1992-99 (when gamekeepers were active on the estate) and 2000-06 (when gamekeepers were not present), the number of breeding Lapwing pairs declined from 0.38 to 0.01 per km², (Baines et al., 2008). This reduction was largely attributed to Carrion Crows and Red Foxes which increased in abundance after control efforts ended, although it is not possible to disentangle their relative effects. Crow abundance increased to approximately four-fold the level under game management. Although Red Fox abundance was not monitored prior to 2000, the number of scats (used as a relative measure of abundance) increased approximately three-fold between 2002 and 2005. No information on mustelid abundance or population trends during this time is available.

The timing of the population crash at Langholm suggests that decreased habitat suitability, which would be expected to exert an influence over a longer period of time, was not the main cause, and that the decline was driven by increases in generalist predators. However, at the time of the most recent review of this project, Lapwing numbers had still not recovered despite the ongoing control of generalist predators there since 2007 (Langholm Moor Demonstration Project, 2014). This suggests that other factors such as habitat or predation by raptors may be contributing. Amar et al. (2008) previously provided evidence that Lapwing populations at Langholm were unlikely to be negatively affected by Hen Harrier or Peregrine predation, but the potential for Buzzards to impact on Lapwings and other moorland birds remains uncertain.

Sub-lethal effects

In a population of Lapwing breeding in central Sweden, although predation caused only 14% of recorded nest losses (the majority of nests were destroyed by agricultural activities), predation risk appeared to exert an influence on nesting behaviour (Berg et al., 1992). Lapwing avoided nesting near trees (associated with higher predation rates) and also tended to nest in colonies, where nest survival rates were higher than for solitary nests. A study of meadow breeding bird assemblages in the Netherlands similarly found that Lapwings and other species preferred nesting in open landscapes, with little cover of forests or built up areas (van der Vliet et al., 2008). This study also identified a direct relationship between presence of avian predators' nests and the density of breeding meadow bird species.

A study of breeding waders in Shetland identified an interaction between corvid predator density and sward height on Lapwing territoriality, which was taken as an indication of the number of pairs willing to breed (van der Wal and Palmer, 2008). In areas with few predators, Lapwing, sward height had no effect on territoriality, but in areas with many predators, Lapwing exhibited territorial behaviour only in areas with long grass.

Prey and predator factors that can modify predation risk

Several studies have shown that higher density Lapwing populations tend to experience lower rates of both nest and chick predation (Berg, 1996; Eglington et al., 2008; Kamp et al., 2015; 2008a; Seymour et al., 2003), and their density may even be a better predictor of predation losses than predator densities (MacDonald and Bolton, 2008b). Possible reasons for this include the improved ability of higher density populations to mob predators and/or because Lapwing are able to identify areas of low predation pressure and settle at higher densities at such sites (MacDonald and Bolton, 2008b). The influence of density-dependence on effectiveness of nest defence behaviour means that any factor that impacts on population size could be reinforced through an interaction with predation risk (Wilson et al., 2004a).

Pre-control predator densities may also have an influence on determining the effectiveness of predator control strategies. Bolton et al. (2007) found that control programmes that were successful in reducing densities of Red Fox and Carrion Crow by a factor of two had no significant effect on Lapwing numbers, except in areas where pre-control predator densities were highest. Early warning of danger from breeding Black-headed Gulls may at least partly compensate Lapwing for any risk of nest predation posed by this species (Thompson and Barnard, 1983).

Other drivers of change

Climate and weather

Climate change may have benefitted Lapwings as populations, and juvenile and adult survival correlate positively with winter temperature (Hudson, 1994; Peach et al., 1994). Evidence of other direct effects of weather include positive correlations between populations and spring flood levels (Berg et al., 2002) and soil moisture (Calladine et al., 2014a), and between juvenile and adult survival and winter rainfall (Peach et al., 1994). These relationships may arise because surface invertebrates become harder to find if the soil is too dry (Hudson et al., 1994) and increased summer temperature and droughts may therefore be detrimental. There are likely to be negative indirect effects of climate change because of its effect on land-use and their impacts may exceed the impact of direct effects. In the Netherlands, models predicted that land-use change scenarios related indirectly to climate change, for example a conversion of grassland to bioenergy crops, would generally lead to reduced populations of Lapwings (van Dijk et al., 2015).

Habitat and land-use

The causes of Lapwing declines have been extensively researched and habitat factors are commonly found to influence their decline, due to alterations to food availability and predation risk. Hudson et al. (1994) has written an extensive review of the impact of agricultural changes in the UK on Lapwing populations. They identified habitat loss as likely to have been the main driver of Lapwing decline since the mid-19th century (Hudson et al., 1994). The rapid declines in the 1980s were probably due to agricultural change, in particular (1) a switch from spring-sown to autumn-sown crops which are too high for breeding Lapwing by spring (Milsom, 2005); (2) draining pastures (Taylor and Grant, 2004) and high levels of nitrogenous fertiliser added, which produces sward that is either too dense for Lapwing chicks to move in (Evans, 2004), allows higher stocking densities producing a higher

trampling risk or increases in silage production instead of hay which allows more and earlier cuts per season; and (3) a decline in rotational farming, reducing the farming mosaic which reduces suitable habitat (Wilson, 1978; Hudson et al., 1994). However, Milsom (2005) found that while the switch from spring to autumn-sown crops was detrimental to Lapwings, it could not explain the extent of their decline. Berg et al. (2015) found that Lapwings avoided heterogeneous farmland areas in Sweden. Some positive effects of heterogeneous cropping may be due to lower pesticide use in mixed crops which leads to higher invertebrate abundance (Hudson et al., 1994; Henderson et al., 2009).

Lapwing population declines have also been attributed to the conversion of unimproved grassland and arable land to improved grassland (Chamberlain and Fuller, 2000; Taylor and Grant, 2004). A review by Eglington (2009) found that they favoured wet grasslands, poorly drained moors and rough grass fields. A Scottish study found that breeding success was lower on arable fields than on rough grazing land despite predation being higher on the rough grazing land (Hudson, 1994). However, Lapwings were positively associated with the amount of intensive grassland in the surrounding area (Dallimer et al., 2010). In England Lapwings declined most in arable regions (Chamberlain and Fuller, 2001) while they declined most in open plains and forest regions in Sweden (Wretenberg et al., 2007).

Some research indicates that Lapwings favour short tussocky sward (Eglington, 2009) while another study found a curvilinear relationship between Lapwing abundance and cereal and grass cover (Sanderson et al., 2009). High sward is likely to reduce the ability of Lapwings to detect predators and actively protect their nests and find invertebrate food (Hudson et al., 1994; Durant et al., 2008). They have a preference for breeding on bare ground (Chamberlain et al., 2009a). Lapwing chick condition was better around wet features on grasslands and it is likely that this was because of the high abundance of invertebrates that they supported (Eglington et al., 2010). Lapwing nest survival increased with spring and summer fallow ground (Sheldon et al., 2007) and abundance correlated with winter stubble (Gillings et al., 2005a) and winter cereals (Gillings et al., 2010).

Variation in predation risk due to habitat factors is likely to have had a large impact on Lapwing populations. Nest predation rates are typically higher in grassland than in some types of arable farmland, where farming operations typically have a greater impact on nest survival (Berg et al., 1992; Galbraith, 1988). One study reports that nests on both types of farmland have higher rates of failure due to predation than nests in ex-industrial 'brown field' sites (Kamp et al., 2015). Park et al. (2005) note that, in addition to its direct effects on Lapwing, agricultural improvement is associated with increased rates of predation in this species (e.g. Baines, 1990).

In some parts of Scotland, such as the south-west, direct loss of suitable habitat to afforestation has been considerable (Ratcliffe, 2007). Lapwing abundance was positively correlated with distance from woodland (Chamberlain et al., 2009a) and field boundaries (MacDonald and Bolton, 2008b) and negatively with length of wood edge (Sanderson et al., 2009), relationships which are likely to be due to increased predation risk near woodland and field boundaries. Lapwings avoided nest sites near avian predators, particularly within 300m (van der Vliet et al., 2008) and high sward is likely to reduce ability to detect predators (Hudson, 1994).

Agrochemicals

Rapid declines of Lapwing in the 1980s were probably due to agricultural intensification and one of the factors associated with this is the addition of nitrogenous fertiliser which can produce sward that is too dense for Lapwing chicks to move in (Hudson, 1994). Increases in fertiliser can also lead to higher stocking densities which increases trampling risk, and increases in silage cutting which allows more and earlier cuts per season, increasing the risk of mortality due to farming operations (Hudson, 1994). Increases in vegetation density may also increase nest predation risk for Lapwings (Evans, 2004).

Non-predation animal impacts

High grazing levels are likely to be detrimental for Lapwing populations (O'Brien and Wilson, 2011) and some of their decline has been attributed to increases in cattle (Chamberlain and Fuller, 2000). Even at very low stocking densities, livestock reduce breeding densities of Lapwings by increasing the predation risk and disrupting incubation schedules (Hart et al., 2002). However, Lapwings are less vulnerable to trampling than other waders on Machair because they lay their eggs earlier than other species (Wilson, 1978).

Other human impacts

Lapwing declines are likely to be driven by low breeding success (Eglington, 2009) and although predation was identified as the main cause of egg and chick mortality, particularly on grassland (Sheldon et al., 2007; Eglington, 2009; Kamp et al., 2015; Schekkerman et al., 2009), farming operations are probably important for this species (Eglington, 2009). Under some circumstances farming operations were the major cause of mortality. In particular farming operations could account for respectively 85%, 48% and up to 63% of Lapwing nest failures on unsown tilled fields in Sweden (Berg et al., 1992), arable land in Germany (Kamp et al., 2015) and arable farms in the South of England (Sheldon et al., 2007). However, the fact that Lapwings often lay replacement clutches after failing at egg stage (Shrubb, 2007) means that this species can tolerate high rates of nest loss (whether to predation or agricultural activities) early in the breeding season, so long as subsequent clutches experience higher rates of success.

Other environmental impacts

Lapwing abundance was higher on less peaty and less acidic soils (McCallum et al., 2015). A review by Eglington (2009) found no information on the impact of pollution on Lapwings.

FOCAL SPECIES - GOLDEN PLOVER

Golden Plover are short distance migrants whose populations appear to be influenced by both survival and breeding success, and there were examples of population abundance being affected by weather, habitat and predation. Even where losses of eggs or chicks to one or more predators are relatively high, the potential for predator control to increase the productivity of Golden Plover

populations may be constrained by other factors, such as food availability (Pearce-Higgins and Yalden, 2003), or predation by other predators (Parr, 1993). Losses of eggs and chicks to predators in such a situation are compensatory, taking the place of (rather than adding to) losses due to other factors. In such cases, the impact of predation on population growth rates could be over-estimated if based solely on observed predation rates. Equally, however, modelling work by Pearce-Higgins (2011), along with experimental studies by Carroll et al. (2011) suggest that the negative impacts of other factors (such as climate change) on Golden Plover populations could be mitigated, at least in some situations, by alleviating current impacts of predation (among other population drivers).

Predation

Importance of different predator species

Experimental reductions of predator numbers in two large studies have successfully increased breeding success and numbers of Golden Plover, but it isn't possible to distinguish between the effects of Red Fox and Carrion Crow in these studies (Baines et al., 2008; Fletcher et al., 2010). The main predator of Golden Plover in a critically declining population of Golden Plover in Saxony was Red Fox (Degen, 2008; Exo, 2005).

Effects on productivity, survival and population size

Egg predation rates in Golden Plover populations can be very high; Byrkjedal (1987) estimated that 78.2% of nests were predated in a Norwegian population.

The decline to extinction of a Golden Plover breeding population in north-east Scotland appears to have been driven primarily by poor survival on its wintering grounds during periods of cold weather in the 1970s and 1980s. It is likely, however, that, predation during the breeding season contributed to this decline by reducing the resilience of the population, making it less able to recover to previous levels (Parr, 1992). Densities of Golden Plover on moorland managed for grouse were higher than on other areas of moor, and appeared to be positively related to intensity of heather burning and size of grouse bag (Tharme et al., 2001). Mammalian predators weren't looked at by this study, but densities of corvids and raptors were also related to grouse moor management. Hen Harrier and Merlin densities were lower on grouse moors (differences in densities of the former species being much more pronounced), while Buzzard densities were higher. Following the cessation of game management in 2000 at Langholm estate the number of breeding pairs of Golden Plover declined by a factor of 1.8 (Baines et al., 2008), a reduction largely attributed to nest and chick predation by Carrion Crows and Red Foxes although it is not possible to disentangle their relative effects.

Following experimental reductions in Red Fox and Carrion Crow abundance (see also the section on Curlew), the breeding success and the density of breeding pairs of Golden Plover increased (Fletcher et al. 2010). The percentage of pairs fledging young rose from $18 \pm 8\%$ (no predator control) to $75 \pm 8\%$ (predator control). Breeding densities were also positively associated with predator control the previous year although the variance in this efficacy was large, with density increasing by $36 \pm 31\%$ per year. In contrast, in the year following no predator control densities reduced by $29 \pm 15\%$.

Golden Plover are almost extinct in western continental Europe with two isolated populations in Germany and Denmark (Exo 2005). Low breeding success was identified as a key proximate cause of this decline with an average of 0.44 chicks per pair fledged annually between 1999 and 2003. Predation by Red Foxes and clutch destruction during peat excavation were identified as the primary cause of loss during incubation and the first two weeks after hatching (Exo 2005). In an effort to conserve the population in Germany, nests were protected from 2004 to 2007, using electric fences, olfactory deterrence and a night-time guard, resulting in an increase in nest numbers from three to seven and no eggs lost to predators (Degen 2008). Of 55 chicks followed, 35 (64%) successfully fledged and 20 (36%) were lost; with foxes taking 9 of these (16%).

Prey and predator factors that can modify predation risk

Early warning of danger from breeding Black-headed Gulls may at least partly compensate Golden Plover for any nest predation carried out by nearby Black-headed Gulls (Thompson and Barnard, 1983).

Other drivers of change

Climate and weather

It is likely that Golden Plover will decline in response to climate change. Warm winter and breeding season temperatures appear to be beneficial to Golden Plovers. In northeast Scotland large declines in Golden Plovers were caused by severe winters (Parr, 1992), and Golden Plover breeding success has been positively correlated with daily minimum temperatures (Douglas and Pearce-Higgins, 2014). However, there is evidence that climate-driven phenological mismatch is detrimental to Golden Plovers, their phenology having advanced at a slower rate than that of their main food source, craneflies. Cranefly larval survival (and, consequently, Golden Plover abundance) in peatland habitats is positively related to soil moisture, and so affected negatively by summer temperatures and management activities such as drainage (Pearce-Higgins et al., 2010). Models predict that climate change could reduce breeding success by 11% by the end of the 21st century. (Pearce-Higgins et al., 2005). To maintain a stable population under a 1°C temperature increase, models predict that Cranefly abundance would need to double, or else nest and chick survival would have to increase by 35% (Pearce-Higgins, 2011).

Habitat and land-use

Habitat has a major impact on Golden Plover abundance and breeding success (Liley and Sutherland, 2007). Golden Plover breeding density correlates negatively with vegetation height, probably reflecting prey availability (Pearce-Higgins and Grant, 2006; Douglas and Pearce-Higgins, 2014) and were negatively associated with intensive grassland management in the surrounding area (Dallimer et al., 2010). However, the extinction of Golden Plover in the north east of Scotland was not associated with a loss of breeding or summer feeding habitat and instead was linked to low winter survival and/or emigration rather than breeding success (Parr, 1992). Poor breeding success due to high nest predation may have prevented population recovery (Parr, 1992).

In some parts of Scotland, direct loss of suitable habitat for Golden Plover to afforestation has been considerable (Stroud et al., 1987). Afforestation is also likely to have an influence on the value of adjacent, open habitats. Forest edges have been found to have negative effects on some waders, probably due to increased predation risks. Amar et al. (2011b) found that declines in numbers of breeding Golden Plover were largest in areas close to forests. A more recent study in the Flow Country of Caithness and Sutherland confirmed this trend, showing that after taking account of differences in vegetation Golden Plover abundance was positively correlated with distance from forest edges (Wilson et al., 2014).

Disease and parasites

In a study in northern England, Golden Plover chick body condition was not found to be affected by tick burden (Newborn et al., 2009).

Other human impacts

There was mixed evidence about the impact of recreational disturbance on Golden Plover, with some studies identifying an impact (Liley & Sutherland, 2007; Showler et al., 2010) and others finding none except in exceptional circumstances (Pearce-Higgins et al., 2007).

FOCAL SPECIES - OYSTERCATCHER

A recent assessment of Eurasian Oystercatcher concluded that populations are stable or increasing over much of their large global range but that drivers are not well understood (van de Pol et al., 2014). However, the BirdLife assessment for the European Red List (BirdLife International, 2015) is that this species is undergoing rapid decline in the European part of its range. There is little research into whether populations are driven by survival or breeding success.

Predation

Importance of different predator species

The only studies sourced for this review which inform on the impacts of mammalian predation are those of introduced European Hedgehogs in the Outer Hebrides in Scotland (Jackson and Green, 2000; Jackson et al., 2004). Avian predators of Oystercatchers on the Uists, include Raven, Hooded Crow, and large gull species (Wilson, 1978). Particularly in coastal situations, the breeding success of Oystercatchers breeding in close proximity to breeding gulls can be kept at very low levels due to gull predation of eggs and chicks. On the Isle of May, Herring Gulls and Lesser Black-backed Gulls kept productivity of Oystercatchers at an annual average of 0.33 chicks per breeding attempt, despite a culling programme that reduced and maintained gull numbers on the island to less than a quarter of their peak numbers (Harris and Wanless, 1997).

Effects on productivity, survival and population size

Following introduction of Hedgehogs to the Uists in the Outer Hebrides, failure rates of Oystercatcher nests due to hedgehog predation were lower than for five other wading bird species, and the density of breeding adults actually increased (Jackson & Green 2000; Jackson et al. 2004). The difference between the fate of this and other species (see, for example, the section on Lapwing) was attributed to the large size of Oystercatchers and their aggressive nest defence behaviour which is sufficient to protect its nest against Hedgehogs. Jackson et al. (2004), however noted that the increase in Oystercatcher abundance in the hedgehog-free northern part of the Uists was considerably higher than those in the south with Hedgehogs (55% vs 21% increase respectively), providing some circumstantial evidence that Hedgehogs may have depressed the expansion of Oystercatcher populations in South Uist.

Other drivers of change

Climate and weather

A severe cold spell of 10 days caused mass mortality of Oystercatchers and death was mainly due to low food availability (Schwemmer et al., 2014). There are also likely indirect effects of climate change because of its effect on land-use that may exceed the impact of direct effects. In the Netherlands, models predicted that land-use change scenarios related indirectly to climate change, for example a conversion of grassland to bioenergy crops, would generally lead to reduced populations of Oystercatchers (van Dijk et al., 2015).

Habitat and land-use

Oystercatchers populations are increasing over much of their range but drivers are not well understood (van de Pol et al., 2014). A review by van de Pol et al. (2014) identified overexploitation by mechanical shell-fisheries, agricultural intensification and reduced eutrophication to be causes of decline in areas where declines were observed (van de Pol et al., 2014). Oystercatchers breed at higher densities in fields with heterogeneous rotation stages (Wilson, 1978), in more open habitats (van der Vliet et al., 2008) and in areas of low soil fertility (Calladine et al., 2014a). They foraged away from ploughed areas with fewer soil invertebrates so food availability may have limited some pairs (Wilson, 1978).

Oystercatcher was one of the species found to avoid nesting in visually occluded landscapes and in close proximity to nests of avian predators (van der Vliet et al., 2008; see Lapwing section for more details). Similarly, corvid density interacted with sward height to affect Oystercatcher nesting behaviour on Shetland in a similar but less pronounced way to that previously described for Lapwings (van der Wal and Palmer, 2008), with territorial behaviour being limited in areas with high predation risk and short grass.

Non-predation animal impacts

Trampling was an important cause of Oystercatcher egg loss, although generally lower than losses to predation (Wilson, 1978) and the populations impacts of this are not known.

Other human impacts

Oystercatchers were found to be negatively impacted by recreational disturbance (Verhulst et al., 2001) and their populations were reduced by 36% up to 1500m from roads, making them the more sensitive to road disturbance than any of the eleven other species studied by Reijnen et al. (1996).

FOCAL SPECIES - CURLEW

A study by Roodbergen et al. (2012) concluded that recent declines of Curlew populations, along with those of other breeding waders in Europe, were caused largely by impacts on productivity. Curlew declines, as with other wader declines, are thought to be due to low breeding success caused by habitat destruction associated with agricultural intensification. These changes can reduce food availability and increase mortality due to predation and farming operations (Eglington, 2009).

Predation

Importance of different predator species

Foxes and small mustelids are the primary mammalian predators of Curlew and other waders (MacDonald and Bolton, 2008a), reducing their breeding success primarily through predation of eggs and chicks. Broschert (2005) identified predation as the major cause of nest loss at sites in the Upper Rhine Valley of Baden (Germany), with the majority of predation events occurring at night and attributed by the authors to Red Fox. A study of breeding Curlew in two areas in Northern Ireland, where productivity was too low to sustain populations in some (Lough Erne, in the south-west) or all years (Antrim, in the north-east), identified predation as the main cause of breeding failure (Grant et al., 1999). The importance of predator type varied between different areas, being dominated by large gulls and corvids in Lough Erne, with mammals (particularly Red Fox) being more important in Antrim (Grant et al., 1999). Control of Carrion Crow and Common Gull increased the hatching success of moorland breeding Curlew in Scotland (Parr, 1993).

At Langholm estate in southern Scotland, raptor numbers increased between 1992 and 1999, likely due to the cessation of illegal killing of raptors and the continued control of generalist ground predators (Amar et al., 2008). Correlational evidence suggests that populations of Curlew and other species of wader breeding on moorland, unlike populations of Meadow Pipit and Skylark, were not adversely affected by raptor predation during this period (Amar et al., 2008), but in the subsequent period, when the intensity of predator management was greatly reduced, the density of Curlew and other waders declined abruptly (Baines et al. 2008). Determining the cause of these declines is complicated by the fact that control of Fox, Stoat, Weasel and Carrion Crow as well as heather burning, all stopped at the same time, and the response of most of these predators to relaxation of control was not well monitored (see below).

Effects on productivity, survival and population size

Two studies from the UK indicate that predators can limit population densities of curlew at some sites; one of these was conducted at a single site and examines prey and predator densities before and after game management ceased (Baines et al. 2008). The other was a replicated experiment controlling a range of predator species whilst ensuring that habitat conditions remained the same (Fletcher et al. 2010).

Following the cessation of game management in 2000 at the Langholm estate in southern Scotland the number of breeding pairs of Curlew declined by a factor of 2.5 (Baines et al. 2008), as did the number of breeding waders of other species, and the numbers of breeding Hen Harriers. After 2000, the availability of suitable nesting habitat, facilitated by heather burning, declined although it was felt that this was likely to have had less of an effect on Curlew densities than predation (Baines et al. 2008). There is also evidence that generalist predator numbers increased during this time (see Lapwing section for more detail).

Fox, Carrion Crow, Stoat and Weasels were all controlled as part of an 8-year experiment testing the effect of predator control on five species of ground-nesting bird species in northern England (Fletcher et al. 2010). Control successfully reduced Fox and crow densities (by 43% and 78% respectively), but had little effect on mustelids which were already scarce. Breeding success of Curlew and the density of breeding pairs increased with predator control. The percentage of pairs fledging young rose from $15 \pm 6\%$ (no predator control) to $51 \pm 9\%$ (predator control). Breeding densities of Curlew were also positively associated with predator control although the increase was more modest and lagged the manipulation by 3-years, this being the typical age at which Curlews first breed. Thus, three years after predator control, breeding densities of curlew increased by $14 \pm 11\%$ per year, whereas in areas without predator control densities reduced by $17 \pm 5\%$ during the same period.

Densities of Curlew and other waders were higher on moorland managed for grouse than on other areas of moor, and appeared to be positively related to size of grouse bag (Tharme et al., 2001). Mammalian predators weren't looked at by this study, but densities of corvids and raptors were also related to grouse moor management. Hen Harrier and Merlin densities were lower on grouse moors (differences in densities of the former species being much more pronounced), while Buzzard densities were higher. Douglas et al. (2014) also found that Curlew breeding density and nest success were both correlated with gamekeeper density, which they used as a surrogate for intensity of predator control.

Prey and predator factors that can modify predation risk

Norrdahl et al. (1995) found that corvid predation of farmland breeding Curlew nests in western Finland were reduced by the nearby presence of breeding Kestrels. Curlew nests were more frequently situated within 400m of Kestrel nests than predicted under an assumption of random distribution. Kestrels took an average of 5.5% of Curlew chicks each breeding season (range from 2% to 12%), but risk of corvid nest predation, as assessed by predation rates on artificial nests, was decreased by proximity to Kestrel nests.

Other drivers of change

Climate and weather

Curlew, a northerly distributed species, is predicted to decline in Britain in response to climate change (Renwick et al., 2012).

Habitat and land-use

Curlew declines, as with other wader declines, are thought to be due to low breeding success caused by habitat destruction: drainage and intensification of farming which affect the availability of nest sites and susceptibility to predation while earlier spring grass growth, earlier cutting dates and higher stocking levels have increased egg and chick mortality (Eglington, 2009). For breeding habitats Curlew were found to favour tussocky vegetation on wet grassland in the lowlands and uplands, poorly drained moors and rough grass fields (Eglington, 2009) where vegetation structure was relatively heterogeneous (Pearce-Higgins and Grant, 2006). Within farmland their breeding density was higher on agricultural set-aside and winter cereals (Gillings et al., 2010) and mixed farmland than on other arable crops (Berg, 1994), although Dallimer et al. (2010) found that their breeding abundance was positively associated with the extent to intensive grassland in the surrounding landscape. Some of the relationships between Curlew populations and habitat may have been caused by the predation risk varying with habitat. Particularly in south-west Scotland and in the flow country of Caithness and Sutherland, direct loss of suitable habitat to afforestation has been considerable (Ratcliffe, 2007; Stroud et al., 1987). Afforestation is also likely to have an influence on the value of adjacent, open habitats. Douglas et al. (2014) found that Curlew breeding success was negatively correlated with the area of woodland surrounding sites, possibly due to higher predation. Predation risk for Curlew nests also appears to be influenced by farm type, with nest predation rates being higher in mixed farming landscapes than where arable farms predominate (MacDonald and Bolton, 2008a). However, Avery (1989) found that Curlew breeding success was not affected by forest proximity once vegetation differences were accounted for and Grant et al. (1999) found that nest failure was not related to vegetation height around nests.

Disease and parasites

Curlew are susceptible to tick infestations and this has been observed to cause some chick mortality in Northern Ireland (Grant et al., 1999). However, tick-induced mortality was minor compared to mortality from predation. In a study in northern England, Curlew chick body condition was not found to be affected by tick burden (Newborn et al., 2009).

Non-predation animal impacts

The impact of trampling on Curlews was reviewed by Eglington (2009) and may be important under some circumstances although nest losses to trampling was generally lower than to predation. Trampling by cattle caused 7% of nest failures in a study in Northern Ireland (Grant et al., 1999) while in sown pasture it was found to account for the loss of 55% of nests (Berg 1992a).

Other human impacts

The impact of disturbance on Curlews is also extensively reviewed in Eglington (2009): recreational disturbance may be associated with the absence of breeding Curlew in the South Pennines (Haworth and Thompson 1990) while Curlew abundance was reduced by the proximity of footpaths in estuaries in England (Burton et al. 2002a and b). Disturbance of feeding birds was predicted to reduce body condition and increased mortality of Curlews (Durrell et al., 2005).

Curlew declines are likely to be driven by low breeding success and although predation was identified as the main cause of egg and chick mortality, farming operations are probably important for this species as reviewed by Eglington (2009). Losses due to farming operations are particularly prevalent in spring cereals and stubbles (Eglington, 2009).

Other environmental factors

Curlew breeding success was not found to be affected by heavy metal pollution in Finland (Currie and Valkama, 1998).

UPLAND GAMEBIRDS

Predation

There is wide recognition (Gibbons et al., 2007; Newton, 1998; Valkama et al., 2005) that gamebirds are among the species whose populations are more commonly regulated or impacted by predation.

Importance of different predator species

Spatial variation in productivity of Capercaillie has been related to crow and Red Fox (though not Pine Marten) abundance (Baines et al., 2004, 2011a). However, Baines et al. (2011b) reported a negative correlation between Capercaillie productivity and abundance of corvids and Pine Marten, and several studies in Scandinavia have shown that Pine Marten can reduce Capercaillie breeding success (e.g. Kastedalen and Wegge, 1989; Kurki et al., 1997). The main cause of failure among Capercaillie released as part of a recovery programme in SW Poland was predation by Pine Marten and Goshawk (Merta et al., 2013).

A 9-year experimental study of Red Grouse predation (Fletcher et al., 2013) included an assessment of predator abundance at each of the four study sites (and, hence, a measure of the effectiveness of predator control). Breeding success was most strongly affected by the abundance of corvids (which were the group of predators most effectively targeted by control), but mammals also affected numbers, with abundance of Red Fox impacting on breeding success, and small mustelid abundance impacting on over-summer adult survival. There was also a significant effect of raptor predation on over-summer mortality of adult Red Grouse (Smith, 2009).

Hen Harriers can, in some circumstances, take sufficient numbers of Red Grouse to impact on breeding productivity (Redpath, 1991), population growth rates and harvestable surpluses available for grouse shooting (Thirgood and Redpath, 2008). Amar et al. (2004) found that Hen Harrier

predation on Red Grouse was more prevalent in areas dominated by heather, where Red Grouse were more abundant, particularly in relation to numbers of alternative prey species.

A Norwegian study in which 34-73 % of Willow Grouse chick mortality was due to predation (Steen and Haugvold, 2009) found that the top three predators (responsible for 76% of all predation where predator was known) were mammals (Stoat, Red Fox and mink). Control of a broad suite of predators (Stoat, Red Fox, mink, marten, Raven and Hooded Crow) had no significant impact on chick survival, implying that the predator control was not sufficiently effective in reducing target populations and/or that some portion of the predation effect that culled animals would have had was manifested by other predators.

Effects on productivity, survival and population size

Fernandez-Olalla et al. (2012) found that Capercaillie population growth rate in the Spanish Pyrenees was more closely associated with recruitment than with adult survival, and was (weakly) positively influenced by control of terrestrial mesopredators. There is good, experimental evidence that generalist predators can reduce Red Grouse breeding productivity, over-summer survival and population growth (e.g. Baines et al., 2008; Fletcher et al., 2013).

Predation and other factors

Tornberg et al. (2013) found correlative evidence that the population dynamics of Capercaillie are affected by densities of other grouse species, through predation by Goshawk. The findings of this, and at least one earlier study (Tornberg, 2001), suggest that the Goshawk population responded (positively) to numbers of Black Grouse and Willow Grouse, but not Capercaillie. In turn, Capercaillie showed a (negative) population response to Goshawk numbers. Wegge & Kastadalen (2007) found that, although predation was proximally responsible a much higher percentage of chick losses (90%) than cold and wet weather (7%), inclement weather was associated with higher rates of predation. Storaas (1988) did not find strong evidence that variation in nest predation rates between different areas was linked with nesting cover.

The population ecology of alpine birds may be particularly susceptible to climate change related effects, some of which may be mediated by interactions with predation risk. Climate change could modify predation risk of Ptarmigan through phenological mismatches in the timing of moult of their seasonally cryptic plumages (Imperio et al., 2013). Extreme weather events can also exert an influence on predation and starvation risk in alpine grouse through the formation of ice-crusts (Menoni et al., 2010).

Evidence for positive effects of predation on prey populations

At low predation rates, modelling work by Dobson and Hudson (1995) suggests that a positive association between parasitism and predation risk could, depending on transmission rates and the consequences of parasitism for individual fitness, increase grouse population growth rates by reducing the regulatory role of parasites. However, such a positive effect of predation has yet to be demonstrated in the field.

Other drivers of change

Climate and weather

Increasing temperatures may lead to declines of upland gamebirds for a number of reasons. Upland birds will have a limited area to shift their ranges into to remain within their current climatic niche (Renwick et al., 2012). Aspects of climate change (including increases in temperature and extreme precipitation events) may lead to more frequent and intense disease outbreaks in Red Grouse which may cause population crashes (Hudson et al., 2006; Thompson et al., 2009). Increasing autumn temperatures can increase predation risk for Ptarmigan because of a mismatch between the timing of changing plumage and the timing of snow arrival, increasing predation risk (Imperio et al., 2013). In a study conducted in the Italian Alps increasing spring temperatures increased Ptarmigan breeding success but this was not predicted to compensate for the increased autumn predation so an overall decline in Ptarmigan populations was predicted (Imperio et al., 2013).

The impact of climate change on Capercaillie is difficult to predict as a number of correlations between weather variables and breeding success have been identified. In Norway a study found that 7% of Capercaillie chicks died directly because of cold and wet weather and predation was higher during and after wet weather (Wegge and Kastdalen, 2007). Capercaillie breeding success was associated with a number of weather variables: it was negatively associated with April temperatures and hatching rainfall and positively associated with the increase in temperature between the beginning and end of April and the hatching temperature (Baines et al., 2011b). Sudden formation of an ice crust can trap and kill Capercaillie sleeping in snow burrows. Ice crusts can also prevent access to food and increase the risk of predation if they are under the ice crust. It is likely that some local population crashes have been caused by ice crusts leading to starvation (Menoni et al., 2010).

Habitat and land-use

It is not clear whether the effect of habitats on Red Grouse was caused by predation risk or food abundance but simulation models indicated that environmental variation and habitat change, rather than predation, had the greatest impact on large Red Grouse populations over the long term (Macdonald et al., 1999). Red Grouse density positively correlated with heather burning (Tharme et al., 2001; Amar et al., 2004) and abundance increased with heather fertilisation, which increased its ground cover (Watson and O'Hare, 1979). Red Grouse populations did not vary with forest proximity once vegetation differences were accounted for (Avery, 1989). Their population trends were found to be negatively with associated distance from forest edge but this did not correlate with trends in predator populations so it was unlikely to be a direct result of predation and may have been linked to habitat factors such as vegetation type and structure (Hancock et al., 2009).

Capercaillie habitat selection appeared to be related to food abundance. Capercaillie breeding success was highest when bilberry cover was between 15 and 20% (Baines et al., 2004) and management that increased bilberries and spiders increased Capercaillie abundance (Nicoll and Norris, 2010). Capercaillie productivity did not correlate with vegetation height (Summers et al., 2004b) and there was little evidence that changes in forest age structure drove a Capercaillie decline

in Finland (Sirkia et al., 2010). The breeding success of Capercaillie negatively correlated with forest fragmentation by farmland (Kurki et al., 2000), which could be due to variation in predation risk.

Disease and parasites

Red Grouse are one of the few species for which disease (in this case, louping ill, a viral disease transmitted by sheep ticks) has been found to have a likely population-level impact under some circumstances (Newton, 2004). It is likely that ticks and tick-borne diseases have increased partly because of climate change and may lead to future Red Grouse population crashes (Thompson et al., 2009). Disease was not found to be an important cause of death among Red Grouse chicks (Steen and Haugvold, 2009; Irvine et al., 2014). However, predated Red Grouse had more parasitic worms than non-predated Red Grouse in Northern England and experimental reduction in parasite loads showed that parasitic worms increased chances of detection by predators, probably because of increased scent (Hudson et al., 1992). A simulation study examined the effect of selective predation of heavily parasitized Red Grouse and concluded that low, selective predation is likely to increase Red Grouse populations by reducing parasite transmission (Dobson and Hudson, 1995).

Non-predation animal impacts

Red Grouse abundance increased after grazers were removed (Watson and O'Hare, 1979).

Other human impacts

In Scotland, mortality due to fence collisions have been observed in Ptarmigans (Watson, 1979), Capercaillie (Catt et al., 1994; Moss, 2001; Baines & Andrew, 2003; Summers et al., 2010), Black Grouse (Warren & Baines, 2002; Baines & Andrew, 2003; Summers et al., 2010) and Red Grouse (Watson, 1979; Baines & Andrew, 2003). However, there is little research into the effect of these collisions on populations except Capercaillie. Capercaillie populations are likely to have been particularly affected by fence collision mortality as deer fences are more prevalent in their forested habitats than on the open habitats favoured by Ptarmigan and Red Grouse. Catt et al. (1994) found that 32% of Capercaillie mortality in Scotland was due to fence collisions. They found that collision mortality was higher in juveniles and males but the population impact was nevertheless likely to be high (Catt et al., 1994). A simulation study indicated that collision mortality is likely to have caused population declines in Scottish Capercaillie (Moss, 2001). However, fence removal and marking (to make remaining fences more visible) around Capercaillie habitat in the 1990s is likely to have reduced the impact of fence collisions (Summers et al., 2004) and may have prevented Capercaillie population decline (Summers et al., 2010).

Mortality due to collisions with ski infrastructure and power lines has been observed across Europe in upland gamebirds: Ptarmigan (Watson, 1979), Red Grouse (Watson, 1979), Black Grouse and Capercaillie (Bevanger, 1995). However, effects on populations are unclear. Watson (1979) found no evidence of effects of Scottish ski infrastructure on Ptarmigan or Red Grouse populations while Imperio et al. (2013) found that Ptarmigan populations may be affected by ski-infrastructure collisions in the Italian Alps. This cannot be taken as evidence of impacts of ski infrastructure in Scotland because of the differing density and scale of ski infrastructure in Scotland and the Italian Alps. Current research into impacts of collisions with ski infrastructure in Scotland is lacking.

Habitat was found to influence the effect of disturbance in Capercaillie, as they showed a physiological stress responses to human disturbance in dense homogeneous Norway Spruce areas but not in more heterogeneous forest (Thiel et al., 2011).

UPLAND WADERS

Predation

Most upland wader research has focussed on the focal species we cover in detail but all upland waders are likely to be impacted by predation by mammals including Red Foxes, mustelids (e.g. Bellebaum & Bock 2009) and corvids (Amar et al. 2011b). Christian & Hancock (2009) found that the most common cause of failure of Greenshank nests in Sutherland was predation. Out of 51 nests with known outcome, 24% (13) failed due to predation, mostly by Ravens and Hooded Crows. Waders were found to be vulnerable to predation by American Mink in Ireland (Roy et al. 2009).

Other drivers of change

Climate and weather

Population declines in Common Sandpipers are probably largely driven by reductions in adult survival. Adult survival in Common Sandpipers correlated with African over-wintering weather conditions in the northern English populations but not in the southern Scotland population (Pearce-Higgins et al., 2009)

Habitat and land-use

Upland wader populations are commonly affected by habitat. Snipe and other wader populations increased in the UK during the agricultural depression in the early 20th century but are generally now declining. Snipe prefer tall tussocky vegetation and moist, soft, peaty soil that allows easy access to soil invertebrates (Wilson et al., 2004; Smart et al., 2008). Soil conditions were more favourable where grazing was low and flooding was high (Smart et al., 2008). However, Snipe and Dunlin population trends did not vary between bog, heather and grassland habitats (Amar et al., 2011b). Snipe declined near forest edges which may be due to increased predation risk, while Dunlin populations trends were not affected (Amar et al., 2011b). Dunlin densities were lower near forest edges but this did not correlate with trends in predator populations so it was unlikely to be a direct result of predation and may have been linked to habitat factors such as vegetation type and structure (Hancock et al., 2009).

Non-predation animal impacts

Grazing intensity explained wader distribution well but could not explain all of wader population change (Ottvall, 2005). Grazing increased wader nest losses due to trampling and increases in the predation risk (Eglington, 2009). Grazing also decreased Snipe populations (O'Brien and Wilson, 2011) probably because it increased soil hardness and thus reduced the availability of soil invertebrates (Smart et al., 2008).

Other human impacts

Breeding densities of ground-nesting birds including Dunlin have been found to be reduced by recreational disturbance (Showler et al. 2010). Direct mortality of chicks from farming operations such as mowing was observed for Lapwings and Curlew and in a review by Eglington (2009)

concludes that this is likely to affect other grassland waders. However, there is little research on the impacts of farming operations on upland waders other than Curlew.

OTHER UPLAND BIRDS

Most research on other upland birds focusses on ground birds, as the majority of upland species are ground-nesting. The only research on ledge nesting species we review is on Dippers.

Predation

Importance of different predator species

It is likely that increased predation by Hen Harriers following a period of strict law enforcement during which Hen Harrier numbers increased, led to population declines of Meadow Pipit and Skylark (Amar et al., 2008). Reviewing the effects of predation by American Mink populations in Ireland, Roy et al. (2009) found that divers were vulnerable to mink predation. Eighteen of 74 juvenile Whinchat were predated (6 more dying of other causes), mostly by mammals (Tome and Denac, 2012).

Other drivers of change

Climate and weather

Meadow Pipit, a northerly distributed species, is predicted to decline in Britain in response to climate change (Renwick et al., 2012), and this may be applicable to other upland species.

Habitat and land-use

Most research into the effect of habitat on upland ground-nesting passerines has been carried out on Skylarks. Agricultural intensification is likely to have driven some of the declines in Skylarks. Skylark nest density was considerably higher on organic farms and set-aside than on conventional farms, mainly due to differences in availability of nesting habitat (Wilson et al., 1997; Kragten et al., 2008). Skylark densities are predicted to decline by over 10% in the future if there are increases in wheat and oilseed rape crops and a reduction in set-aside as predicted (Boatman et al., 2010).

In a review by Eglington (2009), stream acidification due to afforestation was identified as being the major cause of historic population declines in Dippers.

Agrochemicals

Contaminants from agro-chemicals associated with sheep farming (e.g. Dieldrin) have been found in Dipper eggs but there is little evidence that there are population effects (Eglington, 2009).

Non-predation animal impacts

Meadow Pipit populations in Scotland were higher where there was low intensity grazing than where there was no grazing or high intensity grazing (Evans et al., 2006). Bourne (1988) noted that in

the north west Britain heavy grazing and burning led to topsoil destruction which may lead to a reduction in bird species.

Other human impacts

Ski infrastructure was found to increase populations of Snow Buntings while have little impact on Meadow Pipits and Wheatears (Watson, 1979). Direct mortality of chicks from farming operations such as mowing was observed in Skylarks (Wilson et al., 1997), and may therefore be a cause of mortality for other upland ground-nesting species. However, there was no research into population level impacts and further research is required to determine whether farming operations can drive population changes in Skylarks and other upland ground-nesters.

LOWLAND GAMEBIRDS AND WILDFOWL

Predation

Importance of different predator species

In a review by Smith (2000) predation was identified as the driver that shapes the population fluctuations of many gamebirds. Red fox predation, the main predation of upland birds in Britain, was generally found to be compensatory or weakly additive (Smith, 2000).

In Southern Spain, a similar number of Red-legged Partridges were predated by carnivores and raptors (Buenestado et al., 2009). In the UK, Red Fox and corvids accounted for at least half of all nest predation events at Pheasant nests (Draycott et al., 2008). Declines in rabbits due to disease led to higher predation and subsequent population declines of Red-Legged Partridges (Newton, 1998).

Other drivers of change

Habitat and land-use

The breeding density of Red-legged Partridges closely correlated with the length of hedgerow available and the amount of nettle at the base of the hedge may also influence breeding density (Rands, 1986).

Disease and parasites

Viral diseases in gamebirds were found to have little importance in the 1960s but were more important in the 1980s, while gamebird bacterial diseases are sporadic (Beer, 1990). Fungal diseases are commonly reported in gamebirds but are generally seen in birds that are already sick (Beer, 1990). Red-legged Partridges can be infected by the parasite *Heterakis gallinarum* but in Scotland a low rate of parasite establishment was found and it did not have a significant impact on the body condition of Red-legged Partridges (Tompkins et al., 2002). Under some circumstances disease can be a relatively important cause of Red-legged Partridges mortality. For example, in southern Spain in areas intensively managed for agriculture and game, disease was responsible for over 20% of female

mortality (Buenestado et al., 2009). However, this was much lower in less intensively managed areas. Protozoal diseases in Partridges was reported to have declined by the 1980s due to medication but drug resistance is a risk that could lead to increases (Beer, 1990).

Other human impacts

Hunting reduced Red-legged Partridge survival in Southern Spain (Buenestado et al., 2009). Simulations indicate that hunting of Greylag Geese is likely to have caused population declines in the past but will not at current rates (Trinder et al., 2010). Hunting of Greylag geese declined between 1999 and 2007, probably because of a northwards shift in wintering distribution (Trinder et al., 2010). Models and observations indicated that Grey Partridges are likely to face local extinction where over 50% are shot annually (Watson et al., 2007b).

LOWLAND WADERS

Predation

Importance of different predator species

Sparrowhawks are an important predator of Redshank populations in some wintering sites, both in terms of the direct impact of predation on over-winter survival, and also through the influence of predation risk on aspects of behaviour, including habitat use and flock size, that can in turn influence starvation risk (Cresswell and Quinn, 2011; Cresswell and Whitfield, 2008; Cresswell et al., 2010). In a southern Swedish population of Redshank, where predation was the most common cause of breeding failure, the most commonly observed predator of Redshank eggs and chicks was Hooded Crow, with Raven, Jackdaw, Common Gull, Herring Gull and Red Fox all also observed taking eggs or chicks (Ottvall, 2005).

Effects on productivity, survival and population size

In some years, survival of Redshank nests was as low as 6%, with chick survival from hatching to fledging averaging 18% over 4 years (Ottvall, 2005). Predation was the most common cause of failure. This level of productivity was calculated to be too low to sustain the population without immigration.

Other drivers of change

Climate and weather

Earlier growing seasons may lead to an increase in vegetation height and density, making food for Black-tailed Godwits less accessible and is likely to have a population-level impact (Kleijn et al., 2010). There are also likely indirect effects of climate change because of its effect on land-use that may exceed the impact of direct effects. In the Netherlands, models predicted that land-use change scenarios related indirectly to climate change, for example a conversion of grassland to bioenergy crops, would generally lead to reduced populations of Lapwings, Black-tailed Godwits, Oystercatchers and Redshank (van Dijk et al., 2015). However, there may be some positive impacts: Redshanks reduced their predation avoidance behaviour in cold weather, probably because of the

increased starvation risk, so climate change may increase survival (Cresswell et al., 2010). Sea level rises have resulted in a loss of coastal habitat for Redshank and some other coastal species (Eglington and Noble, 2010).

Habitat and land-use

Lowland waders were affected by habitat features: Redshank breeding density was higher nearer wetland features such as ponds or ditches (Smart et al., 2006). However, manipulating water levels was not found to influence their abundance (O'Brien and Wilson, 2011). Black-tailed Godwit chick survival in herb-rich meadows was 2.5 times higher than on grassland monocultures while in Machair habitats Ring Plover breeding density was higher where fields were at heterogeneous rotation stages and they were absent from land that had been fallow for many years (Wilson, 1978).

It is likely that predation influenced habitat preferences as Redshank foraged in habitats of low Sparrowhawk predation risk except in cold weather when the starvation risk was higher (Cresswell et al., 2010). Corncrake populations increased more where management increased early and late vegetation cover (O'Brien et al., 2006), which may be related to predation risk.

Non-predation animal impacts

Redshank populations have declined, most rapidly in areas where there were high grazing pressures (O'Brien and Wilson, 2011; Malpas et al., 2013b). Grazing increased Redshank nest losses due to trampling and increases in the predation risk (Eglington, 2009): on saltmarshes the risk of predation for Redshank nests was 28% where there was no grazing and 95% at 0.55 cattle per hectare (Sharps et al., 2015). Grazing intensity explained wader distribution well but could not explain all of wader population change (Ottvall, 2005) and moderate grazing may be optimal for maintaining wader populations (Sabatier et al., 2010).

Other human impacts

Recreational disturbance of Ringed Plover reduced their breeding densities and may affect other waders (Showler et al., 2010). Mowing was the cause of 5-10% of Black-tailed Godwit chick mortality in a study in the Netherlands (Schekkerman et al., 2009) and a review by Eglington (2009) concludes that this is likely to affect other grassland waders. Silage cutting was identified as being particularly destructive to Corncrakes (MacDonald, 2006). However, losses to farming operations were generally small compared to losses to predation (Berg et al., 1992; 1997; Eglington, 2009; Kamp et al., 2015). Furthermore, wader population declines (study examined Oystercatcher, Lapwing, Black-tailed Godwit, Curlew and Godwit) did not correlate with nest losses due to farming operations (Roodbergen et al., 2012).

OTHER LOWLAND BIRDS

Predation

Importance of different predator species

In general, the evidence for population impacts of predation on breeding songbirds is weak and declines are generally linked to habitat factors (Gibbons et al., 2007). Looking at the importance of different predator species for woodland songbirds in Europe, Weidinger (2009) found that birds and mammals took roughly equal numbers of prey, with Pine Marten being the most important mammal predator, and Jay being the most important bird. In England, nest predators of Spotted Flycatchers, identified with nest cameras, were mainly avian (mostly Jay) but also commonly cat (Stevens et al., 2008). There was evidence that this nest predation was sufficient to contribute to the long-term population decline of woodland and farmland nesting Spotted Flycatchers (Stevens et al., 2007, 2008), although other factors such as climate change on wintering grounds have also been implicated (Ockendon et al., 2014). Control of a wide suite of predators was successful in increasing Spotted Flycatcher populations (Stoate and Szczur, 2006). Colonisation by Pine Marten and Hooded Crow of two urban parks in Poland coincided with rapid population declines in larger prey species, including Woodpigeon, Collared Dove, Jackdaw, Jay and Blackbird, as well as smaller birds like Tree Sparrow (Tomialojc, 2011). Management including predator control for Pheasants was found to increase local songbird populations but the management also included increased food provision and cover so the effects of predators could not be identified (Stoate et al., 2001).

A number of studies have attempted to determine the impact of the Sparrowhawk population recovery on prey species but results are inconclusive for most species. Analysing BTO's Garden Bird Watch survey dataset, Chamberlain et al. (2009b) found that annual change measures of some bird species (Starling, Greenfinch and Chaffinch) were negatively correlated with Sparrowhawk recolonisation following the ban of organochlorines in the middle of the 20th century. However, population trends of other bird species were positively related to Sparrowhawk recolonisation and, overall, they found no strong evidence that the return of the Sparrowhawk was causally linked with any long-term declines in population size. There was also no major increase in songbird populations that followed Sparrowhawk declines (Newton, 1998). Similarly, analysing Common Bird Census and Breeding Bird Survey datasets from England, Newson et al. (2010) found negative relationships with predators (including Sparrowhawk, Buzzard, Kestrel, Carrion Crow, Magpie, Jay and Grey Squirrel) for only 7 out of 29 prey species they looked at. Furthermore, they conclude that many of these relationships are likely to be spurious, and that their analysis provides little evidence for any strong effect of predator abundance on the population trajectories of most bird species. At a site-based level, Newton et al. (1997), examining variation in the songbird populations of a woodland in relation to organochlorine-induced variation in Sparrowhawk abundance, found no evidence for Sparrowhawk effects on breeding numbers of several species of woodland passerines.

Looking at House Sparrows, in particular, Bell et al. (2010) found that declines at a national level coincided both temporally and spatially with increases in Sparrowhawk numbers. This study has been criticised for not taking environmental correlates into account, but subsequent analysis by Swallow et al. (2015) confirmed a negative relationship between Sparrowhawk and House Sparrow abundance. However, it is not certain whether this relationship is due to a numerical or behavioural response on the part of House Sparrows. MacLeod et al. (2006) found that the mass of House

Sparrows in winter was lower in areas where Sparrowhawks were present, suggesting that the influence of predation risk on mass regulation could expose House Sparrows to higher risk of starvation.

Sub-lethal effects

Proximity of Pied Flycatcher nests to active Sparrowhawk nests was negatively related to body mass, and positively related to levels of stress protein and higher nestling provisioning rates (Thomson et al., 2010). Declining winter Great Tit mass over a period of 10 years in Whytham Woods, Oxford, was explained by an interaction between winter temperature and Sparrowhawk abundance (Cresswell et al., 2009). The influence of increased predation risk on winter mass was contingent on temperature, being negative in cold winters and positive in warmer winters. Predation risk can alter habitat preferences exhibited by species with different anti-predator strategies as seen in a suite of farmland birds (Whittingham et al., 2006)

Predation and other factors

Predation on woodland birds that nest in lower layers of vegetation can be exacerbated by the impact of deer on the availability and structure of low, woody vegetation (Gill and Fuller, 2007). Responses to predation risk also depend on trade-offs between risk of predation and risk of starvation. Proximity to some kinds of edge within the landscape can affect predation risk, though this effect is typically variable between and even within studies (Storch et al., 2005).

Evidence for positive effects of predation on prey populations

Møller & Nielsen (2007) found that individuals taken by Goshawks were more likely to have malaria than non-predated individuals, suggesting that Goshawk predation could result in a population-level benefit through reduced levels of parasite transmission.

Other drivers of change

Climate and weather

Climate change impacts are likely to vary between species but there was little evidence that climate change will be detrimental to lowland birds. Nuthatch and Green Woodpecker, both southerly distributed species, are predicted to have population increases in Britain in response to climate change (Renwick et al., 2012). Increasing winter temperatures may be beneficial for some species as severe winters cause small, inconsistent declines some farmland species, particularly in Reed Buntings (Shrubb, 2003). Adult Long-tailed Tit survival is positively associated with breeding season and autumn temperature and negatively associated with spring precipitation, and climate change is likely to have contributed to their long-term increase in population (Gullett et al., 2014). However, phenological mismatch is likely to have caused declines in Long-tailed Tit productivity (Gullett et al., 2013). Great Tit breeding success correlated with the phenological matching between chick food requirement and availability, but they have altered their laying phenology adequately to match changes in food phenology, suggesting that climate change is unlikely to have affected their breeding success (Charmantier et al., 2008). Furthermore Great Tit and Blue Tit breeding success

was very low in a year with particularly cold and wet spring weather (Whitehouse et al., 2013). There is also evidence that the winter starvation risk for UK Great Tits has declined over time, possibly due to increasing winter temperatures (Cresswell et al., 2009). However, population declines due to phenological mismatch are considered to be a possibility which requires further research. Many woodland species are declining; particularly long-distance migrants and phenological mismatch has been proposed as a possible mechanism for this, with some evidence of population impacts on Pied Flycatchers (Both et al., 2009). For some species including Willow Tits and Lesser Spotted Woodpeckers, food availability may be related to soil moisture so could be affected by climate change (Eglington and Noble, 2010).

Survival of Swallows, House Martins and Sand Martins correlated with rainfall on the African wintering grounds but not with breeding season rainfall in Britain (Robinson et al., 2008). There was no link found between Slavonian Grebe productivity and climate (Brooks et al., 2012).

Habitat and land-use

The effect of habitat on lowland birds varied between species but many farmland species have declined, probably due to agricultural intensification during 1970-1990 (Gibbons et al., 2007). At Allerton, a project established to combine farming and wildlife protection, correlations between songbird populations and crop types were examined (Stoate et al., 2012). Blackbirds and Song Thrush nests were more successful near pastures while Linnets and Reed buntings favoured oilseed rape. Tree Sparrows primarily foraged in field beans while Yellowhammer abundance correlated with millet seed abundance (Stoate et al., 2012). Population declines of Whinchat did not correlate with winter habitat (Hulme and Cresswell, 2012) while Corn Bunting populations correlated with grassland habitats (Brodier et al., 2014). Winter crops planted for gamebirds increased the populations of many songbird species (Sage et al., 2005). Swallow decline in northern Italy was linked to the cessation of livestock farming (Ambrosini et al., 2012).

Many woodland species may have declined partly due to a reduction in active woodland management, and woodland maturation, together with changes in vegetation structure caused by increases in deer populations (Eglington and Noble, 2010). Fragmentation and reduced connectivity may also contribute to the decline in some species (Eglington and Noble, 2010). A reduction in food resources may also be linked to the decline in Lesser Spotted Woodpecker, Bullfinch, Lesser Redpoll and Song Thrush (Eglington and Noble, 2010). Recovery of Nightjar populations is associated with their colonization of clear-fell areas in planted forests (Langston et al., 2007). It is likely that predation risk varies between habitats, particularly for ground-nesting birds. However, Yellow Wagtails preferentially selected some habitats that exposed them to a higher predation risk than less preferable habitats (Gilroy et al., 2011). Breeding success in Spotted Flycatchers varied with habitat and was lower in woodland and farmland than in gardens because of lower nest predation (Stevens et al., 2007). However, breeding success did not correlate with population change so it is unlikely that this had a population effect (Stevens et al., 2007). Great Tits and Blue Tits in mixed deciduous woodland were more vulnerable to poor weather conditions than those in riparian and urban habitats (Whitehouse et al., 2013) while Marsh Tits were much more common on woodland than farmland (Siriwardena, 2006).

In a review by Eglington and Noble (2010), the authors found that there were possible negative impacts of urban development

Agrochemicals

There is little evidence of direct impact of pesticide use on birds but the indirect effects are reviewed by Campbell (1997) and have an impact on many farmland birds. There is a lack of long-term data on invertebrates and plants but evidence suggests that there was a general decline that may be due to pesticide use, particularly for insects (Campbell, 1997). Herbicide use can also reduce nesting cover and allow for increases in grazing densities, sward densities and harvests, and a shift to greater silage production, all of which may lead to bird population declines (Campbell, 1997). In particular there were links between population decline and pesticide use found for linnets, corn buntings and starling (Campbell, 1997). Herbicide use is likely to have played a major role in the decline of seed eating birds (Newton, 2004). Yellowhammer declines since the mid-1980s corresponds to increases in pesticide use (Hart et al., 2006). Brood success positively correlated with arthropod abundance which was lower where insecticides had been used (Hart et al., 2006).

Disease and parasites

Steep declines in Greenfinch and Chaffinch were observed following the emergence of finch trichomonosis in Britain (Robinson et al., 2010; Lawson et al., 2012). Disease may have been responsible for up to 4% of Coot mortality in southwest Poland (Rek, 2009), making population level effects unlikely. Paridae pox reduced the reproductive output of Great Tits and reduced chick, juvenile and adult survival (Lachish et al., 2012). However, at current levels in Britain, disease-induced population decline is unlikely (Lachish et al., 2012).

Non-predation animal impacts

The abundance of song-birds and many understorey birds including several migrants increased with improved vegetation structure caused by the absence of deer (Gill and Fuller, 2007; Martin et al., 2011). Increasing grazing pressure by deer may have caused some declines in woodland birds while some species such as redstart may benefit (Fuller et al., 2005).

High intensity grazing can cause population declines of ground-nesting birds as it leads to increases in nest trampling and may increase predation risk because of increases in sward homogeneity (MacDonald, 2006). Increasing grazing pressure by deer may have caused some declines in woodland birds but some species such as wood warbler may benefit (Fuller et al., 2005). One of the few studies to examine the impacts of competition on non-predatory species found that Marsh Tit populations correlated positively with the populations of potential competitors, indicating no effect of competition (Siriwardena, 2006). However, Fuller et al. (2005) found evidence of interspecific competition among cavity nesters. Great and Blue tits commonly take nests from Willow Tits and there may be some competition between woodpeckers for food (Fuller et al., 2005).

Other human impacts

Recreational disturbance was found to reduce breeding densities of ground-nesting birds including Nightjars (Showler et al., 2010) while disturbance was found reduce Dartford Warbler productivity on heather habitats but not gorse habitats (Murison et al., 2007). There was evidence that farming operations such as mowing were the cause of some chick mortality for lowland ground-nesting birds including Whinchat (MacDonald, 2006) and Corn Bunting (Perkins et al., 2011). Silage cutting was identified as being particularly destructive to Whinchat nests (MacDonald, 2006). Farm operations may be an important driver on population change for some lowland ground-nesting birds as Whinchat population abundance correlated more closely with deaths caused by early mowing than with food abundance (Strebel et al., 2015). Also, Corn Bunting populations were higher on farms under agri-environmental schemes that were specifically tailored to Corn Buntings, and included delayed mowing, than on farms under more general agri-environmental schemes (Perkins et al., 2011). Ski infrastructure was found to increase populations of Pied Wagtails (Watson, 1979).

Other environmental factors

Increases in the breeding success of Slavonian Grebes correlated with increases in phosphorus in Scotland from the early 20th century which led to increases in their main food source, Chironomids (Brooks et al., 2012).

RAPTORS AND CORVIDS

Predation

Productivity of Hen Harriers can be impacted by ground predators, particularly Red Fox (Baines and Richardson, 2013; McMillan, 2014). However, in areas where predator control is practiced, ground predators may have a smaller effect on Hen Harrier breeding success than the actions of humans (Green and Etheridge, 1999; Whitfield et al., 2003, 2008).

A review by Roy et al. (2009) found that in Ireland, upland, ground-nesting raptors and owls, such as Merlin, Hen Harrier and Short-eared Owl, are vulnerable to ground predators such as American Mink, though they didn't back up this general statement with evidence.

Other drivers of change

Climate and weather

Sparrowhawk population growth was negatively related to winter temperature (Millon et al., 2009) so may decline as winter temperatures increase. Hen Harrier productivity correlated positively with May temperatures so may benefit from climate change (Whitfield et al., 2008). Hen Harrier populations and breeding success was also negatively correlated with spring rainfall (Amar et al., 2011a), while Buzzard abundance correlated positively with mean annual rainfall (Gibbons et al., 1995).

Habitat and land-use

Most research on the impact of habitat and land-use on predator abundances has focussed on Golden Eagles and Buzzards. Forest plantations limit Golden Eagle populations in some areas of Scotland (Watson and Whitfield, 2002; Walker et al., 2005) and Golden Eagle productivity was negatively related to forest cover (Whitfield et al., 2007). However, dwarf shrubs harbour medium sized herbivores that Golden Eagles rely on for food in some areas of Scotland (Watson and Whitfield, 2002).

Buzzard breeding success was influenced by habitat quality, probably due to food availability as supplementary feeding could mitigate the negative effect of poor habitat (Rooney et al., 2015). Buzzard nest selection was related to the availability of high trees and the distance from roads (Sergio et al., 2005) while no correlation between Buzzard abundance and habitat openness was found (van der Vliet et al., 2008).

Buzzard and Raven abundances were negatively related to grouse moor management but it was not clear what feature of grouse moor management caused this (Gibbons et al., 1995).

Agrochemicals

Rodenticides are used on over 75% of arable farms in Scotland and they are commonly found in raptor liver tissue (Hughes et al., 2013b). Risks to most raptors was generally considered low except for Red Kite for which at least 10% of mortality was related to rodenticide (Hughes et al., 2013b). In France the impact of rodenticides increased after water vole outbreaks and caused high levels of mortality in Red Kite and Buzzards (Coeurdassier et al., 2014). Research into the impacts of rodent outbreaks in Scotland should be considered. In the 1950s and 1960s declines in Sparrowhawk, Peregrine and Merlin were identified as being caused by pesticides in a review by Newton (2009).

Non-predation animal impacts

Hen harrier population and breeding success was negatively correlated with sheep abundance (Amar et al., 2011a). This is likely to be due to the decline in rough grazing and voles (Amar et al., 2005; Amar et al., 2011a). Where Hen Harrier populations are not reduced by illegal killing, much of the variation in their abundance can be explained by Meadow Pipit and vole abundance (Smith, 2000). Increases in deer and sheep grazing are also likely to have caused a decline in Golden Eagle breeding success in some areas of Scotland because of a reduction in dwarf shrubs which have high abundances of prey (Watson and Whitfield, 2002). However, in other areas of Scotland Golden Eagles depend on sheep and deer carcasses for winter survival (Watson and Whitfield, 2002). In the uplands Buzzards abundance was higher in areas densely stocked with sheep than those with low densities, which may also be due to a high availability of carrion (Gibbons et al., 1995). In general, territorial competition was identified as having the potential to drive population changes in predators (e.g. Dawson et al., 2011). For example, populations of Ravens increased after Hooded Crows were culled on an Irish island (Bodey et al., 2009) while Buzzard populations were thought to increase due to release from competition from Goshawks in Germany (Chakarov and Krueger, 2010).

Other human impacts

There is abundant evidence that Hen Harrier populations are suppressed by illegal persecution in Scotland on grouse moors. Hen Harrier productivity and survival was lower on grouse moors than on other moorland (Etheridge et al., 1997; Green and Etheridge, 1999), while there was no evidence of food stress on grouse moors and legal predator control should have led to increased breeding success, leading the authors to identify illegal killing as the likely cause of low productivity and survival. Hen Harrier population abundance and productivity correlated negatively with the intensity of burning, a proxy for grouse management gamekeeper activity (Anderson et al., 2009). Simulation models by Heinonen et al. (2014) indicated that mortality from illegal killing is important for Hen Harrier populations. Baines & Richardson (2013) and Green & Etheridge (1999) found that Hen Harrier populations increased on Scottish grouse moors after illegal killing ceased. In Wales increases in Hen Harrier productivity correlated with reduced human interference and increasing May temperatures (Whitfield et al., 2008).

It is likely that Hen Harriers are not the only raptor species that is affected by illegal killing associated with grouse moors. Historical records of raptor persecution indicate that illegal killing continued after the implementation of raptor protection legislation (McMillan, 2011) and illegal poison baits were found disproportionately often on grouse moors than other moorland (Whitfield et al., 2003). A review by Watson and Whitfield (2002) found that Golden Eagle populations were limited in some areas of Scotland by deliberate and accidental killing, mainly through poisoning. Peregrine productivity was 50% lower in nests on actively managed grouse moors but clutch and brood size of successful nests did not differ between grouse moors and other moorland, indicating that food constraints were unlikely to explain the difference (Amar et al., 2012). Furthermore, wildlife crime data confirm that illegal killing of Peregrines was higher on grouse moors than elsewhere (Amar et al., 2012), and Peregrine territorial occupancy and breeding success are negatively related to grouse moor management in North-East Scotland (North East Scotland Raptor Study Group, 2015). Buzzard and Raven abundance was also negatively correlated with grouse moor management although differences in habitat food availability could not be ruled out (Gibbons et al., 1995).

Other human impacts include the impact of ski infrastructure, windfarms and roads although there was little research on the impacts of these on predators. Ski infrastructure was found to increase populations of Carrion Crows and Rooks (Watson, 1979). Golden Eagles changed their range to avoid a windfarm site (Walker et al., 2005). Ramsden et al., (2006) found that Barn Owl mortality due to road traffic was high enough to be a likely driver of population change.

5.2 Stakeholder understanding of population drivers of wild birds and their predators

5.2.1 Environmental and human drivers of population change

5.2.1.1 Questionnaire results

For each of the six prey species there were significant differences in the eight factors selected by the Local Knowledge and Scientific Knowledge groups. Likelihood Ratio Chi-Square > 17.93, DF = 7, $P < 0.012$). The greatest difference was for the importance of predators, with an average of 75% of

respondents in the Local Knowledge group considering predators have had a medium to high negative impact on the six prey species, compared to an average of 41% amongst the Scientific Knowledge group (Figure 19). In contrast, the proportion of respondents considering habitat to have had a medium to high negative impact was smaller for Local Knowledge group (36%) than for the Scientific Knowledge group (53%). There were two other differences between the groups that were consistent across the six prey species. On average, 26% of respondents in the Local Knowledge group considered disturbance to be an important factor compared to 17% in the Scientific Knowledge group. In contrast, those in the Scientific Knowledge group were more likely (11%) to answer 'Don't Know' than those in the Local Knowledge group (5%).

Additional factors that were considered to have had a medium to high negative impact on one or more of the prey species were named by 18% of respondents (Table 10). Factors relating to changing agricultural or farming practices were mentioned most commonly. Modern agricultural or farming practices were considered to impact on all six prey species (average of 17 mentions across all six species) but were more often thought to have impacted on Curlew, Grey Partridge, Lapwing and Oystercatcher than on Black Grouse and Golden Plover.

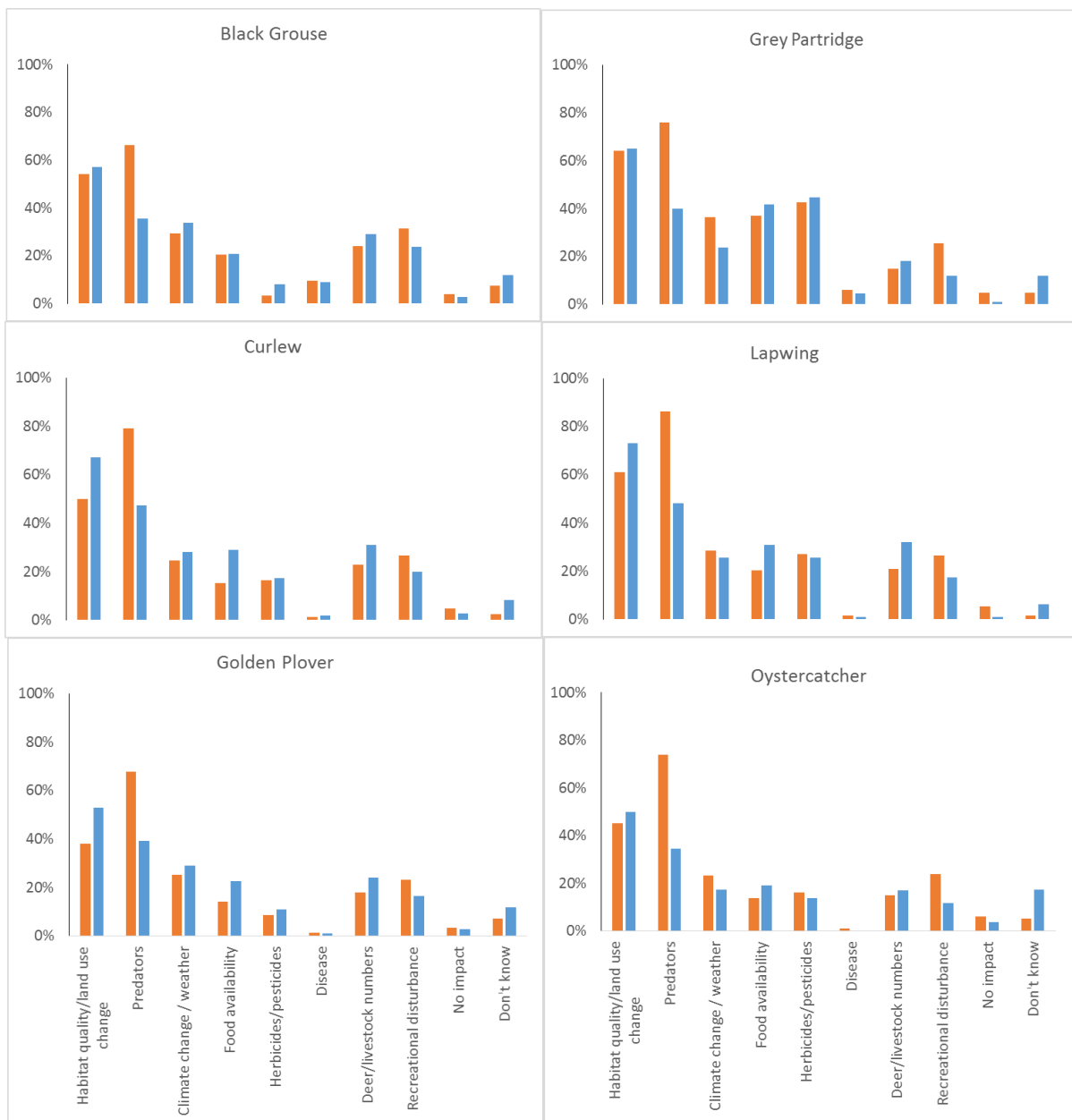


Figure 19. Percentage of Local Knowledge (orange bars) and Scientific Knowledge (blue bars) respondents who identified different environmental and human factors as having had a medium to high negative impact on the six prey species over the last 25 years. Respondents could identify more than one factor (n=321).

5.2.1.2 Workshop results

Participants in both local and scientific knowledge workshop groups identified predators as an important driver of population change for the six focal prey species, however the relative importance placed by the two knowledge groups on predators compared to other drivers differed somewhat. Local knowledge workshop participants and participants from one scientific knowledge group prioritised predators over the other drivers but also strongly associated land-use change with focal species population decline. Participants from the other two scientific knowledge groups prioritised habitat quality and land-use change over predators as the most important drivers. Local knowledge groups tended to rank recreational disturbance more highly than did scientific workshop groups. There was general agreement about the relative importance of food availability, climate/weather and livestock numbers regarding focal species population decline. All workshop groups identified herbicides/pesticides as an important driver of population change for Grey Partridge in particular. Both local and scientific knowledge groups agreed that drivers like predators, land-use change and weather can interact to stimulate predator and prey population changes and that measuring the impacts of any single driver in isolation can be problematic *“None of these effects are wholly consistent across Scotland at all scales, nor do they operate alone, but rather synergistically”* (SK#3).

Table 10. Five most commonly mentioned ‘other’ environmental and human factors perceived to have had a ‘significant’ (medium to high) negative impact on the six species of ground-nesting wild birds, showing proportion of respondents mentioning each impact, in order of total number of mentions for all prey species combined. Source: questionnaire respondents, n=69.

	Black Grouse	Curlew	Golden Plover	Grey Partridge	Lapwing	Oystercatcher	Total mentions
Agricultural/farming practices	1%	5%	2%	5%	6%	5%	101
Ticks	2%	2%	2%	1%	2%	1%	41
Lack of predator control	1%	1%	1%	1%	1%	1%	34
Other human factors	0%	0%	0%	0%	1%	1%	14
Wind farms/turbines	0%	1%	1%	0%	0%	0%	12

PREDATION

Perhaps one of the most important reasons why local knowledge participants prioritised predator impacts over other kinds of impacts is due to the significant amount of time they spend observing wildlife and the increasing frequency with which they witness or hear about predators or predation events. Partly, this was due to the nature of their professional roles where monitoring predators is a high priority for some land managers “...we’re doing it 365 days a year, constantly... that’s why it’s so important” (LK#5). Intimate knowledge of the land also led to concerns being raised about the increase in variety of predator species and in number of individual predators negatively impacting on potential survival of a range of prey species populations, including various protected species. Numerous examples were cited by local knowledge participants of how local observations have predicted wader declines in different areas due to the impacts of predators (e.g. hedgehogs predating wader eggs on the Uists, Pine Marten predating Capercaillie eggs).

Local and scientific knowledge workshop participants identified several recent changes which they perceive are related to increased negative impacts of predators on ground-nesting birds.

One of the most important changes identified relates to habitat degradation associated with land-use change, partly due to national afforestation strategies, farming intensification, inappropriate muirburn and grazing regimes and “a cultural move away from the land and good land management” (LK#3). It was suggested that in cases where the proximate cause for unsustainably high predation is linked to high predator densities, the ultimate cause for the unsustainably high predation might be land-use that creates favourable conditions for generalist predators such as commercial forest plantations (a haven for foxes) or pheasant releases (e.g. increased food abundance for foxes and crows). Predation was said to be worse where habitat quality was poor, that is, available cover increasingly benefits predator rather than prey species “*Drainage of wet areas and the homogenisation of the landscape make foraging difficult for waders and potentially make them easier to locate by predators*” (SK#2).

A recent decline in predator control effort, partly due to greater regulation of keeping practices, was thought to be related to an increase in meso-predator abundance, which is exacerbated by increasing populations of some protected predator species “*My experience is where predator control is absent these species are really struggling. That and the inability to control predator species such as Buzzards and Ravens is having a hugely negative impact on ground-nesting birds*” (LK#5).

Growing population size and range of many predator species (e.g. Buzzard, Badger, Carrion Crow, Pine Marten, Raven, Red Fox) were described as intensifying predator impacts due to various opportunistic species interacting with each other and taking advantage of evermore vulnerable ground-nesting birds throughout their life cycle. An increase in avian predators coupled with decrease in density of some semi-colonially nesting species (e.g. Lapwing) was thought to make some prey defence strategies less effective. As a result, soaring egg predation and chick mortality rates were identified as major causes of ground-nesting bird species population decline. “*Foxes, crows, Ravens, Stoats and Buzzards even in small numbers when all are present can have a negative impact on all of the listed wild bird species. The main damage being hen birds predated by foxes and nests predated, and wader chicks roaming free once hatched are very vulnerable to crows, Ravens and Buzzards*” (LK#1).

Predators were also said to detrimentally affect prey behaviour *“We know that as well as directly reducing abundance through predation, in some circumstances predators can affect the habitat use and physiology of their prey, so it is possible that research might uncover similar effects here. E.g. ground-nesting birds may avoid areas with high densities of crows or Buzzards, etc., or they may be in poorer body condition because they are 'forced' to forage in poorer habitats, with consequent impacts on reproduction and survival”* (SK#3).

Another recent change identified by some local knowledge participants was the introduction of the *“right to roam”* as part of the Land Reform (Scotland) Act 2003 leading to greater frequency of ground-nesting bird disturbance by walkers and their dogs. Disturbance was linked to predation, particularly at breeding times when bold, intelligent species (e.g. corvids) take advantage by predating on unguarded eggs or adopting abandoned nests.

However, there was scepticism among some scientific knowledge participants about the link some local knowledge holders make between increasing predator and decreasing ground-nesting bird populations. Difficulties in assessing the impacts of predators on ground-nesting bird species were acknowledged with perhaps the most important of these being inconsistency in the effects of predation *“...across scales and ranges and not all impacts at given abundances of predators will always result in population scale effects on the prey species”* (SK#3).

Predator disturbance

Participants from three local and one scientific knowledge group discussed the negative effects of predator disturbance on both prey and predator species. Predators (e.g. Red Kites, Buzzards and Otters) were said to often scatter ground-nesting birds (e.g. grouse chicks), which can significantly disrupt normal feeding, breeding or preening patterns (e.g. Black Cock cancelling their lek or lekking at night), or cause them to become stressed and more vulnerable to predation or adverse weather conditions. This can be especially detrimental for waders with flock nesting defence mechanisms *“Constant disturbance of adults defending nests and young keeps the adults from parenting. When numbers of waders becomes low... the defence mechanism of mass mobbing does not work so predation becomes easier”* (SK#3). Buzzards were also described as taking prey from other avian predators, increasing the cumulative impact of predation overall *“Have seen Buzzards attacking Kestrels and taking the mice etc. off them too”* (LK#2).

OTHER DRIVERS OF CHANGE

Habitat and land-use impacts

While both local and scientific knowledge workshop participants identified loss of habitat quality and inappropriate land-use change as important drivers of population decline, some scientific knowledge workshop participants prioritised the importance of habitat quality over all other drivers.

Appropriate habitat was identified as critical for species presence *“You can do as much predator control as you want but you’ll not get Lapwings to nest successfully in a car park, you’ve got to have the right habitat to underpin it”* (SK#3). On the one hand, optimal habitat was described by some scientific knowledge participants as continuous and connected, such as that found in some other European countries, because this can support resilient populations at a landscape scale. However, the concept of *“resilience through connectivity”* was said by one scientific group to have little applicability in the UK due to fragmented habitats at a landscape scale. On the other hand, some

local knowledge participants with long term knowledge of their own local “*patch*” valued diverse habitats, saying Scotland has “*been made fantastic by the land managers following their own interests and being allowed to create little havens of all sorts of different things and for diversity*” (LK#6).

Discussions about habitat quality were often linked to land-use change or land management practices. Some species (e.g. Snipe, Oystercatcher) in certain areas or circumstances were said to have benefitted from land-use change (e.g. flat industrial roofs or brown field sites benefitting Oystercatcher) or farming or forestry practices that have temporarily suited their ecological niches “*...Black Grouse... appear to value transitory habitats*” (SK#3). However, local and scientific knowledge participants more often talked about interactions between different drivers having a cumulative negative impact (e.g. farming practices, intensive agricultural practices and forestry plantation management), muirburn and grazing regimes and reduced food availability for prey “*Poland, Hungary... Turkey, these are all places that have much less intensive agriculture and as a consequence better prey... species abundance particularly farmland birds, much higher numbers of species that used to occur in Britain ... that have now become extinct in this country*” (SK#2). Some also linked habitat quality and land-use change with climate change “*When we collect this long-term data like grouse counts for example the whole land-use change issue happening at the same time, the forest comes and goes and habitat is always changing... predator numbers go up and down three fold and in the background climate change is ticking on*” (SK#2). Habitat quality and land-use change were also often linked to predator numbers and reduced predator control measures in some places “*...predators are the business end of land-use change*” (LK#6). Some said even though good numbers of breeding birds may exist in an area with sub-optimal habitat, predator control might still be required “*I think some investment into change of land-use and habitat, to help Black Grouse in particular, has been positive... but due to lack of predator control or high numbers of predators that are unable to be controlled the Black Grouse have failed to increase in numbers or have disappeared altogether*” (LK#5).

Afforestation

Participants from five local knowledge and two scientific knowledge workshop groups talked about afforestation. They were particularly concerned about the detrimental impact on ground-nesting birds of commercial forestry plantations and associated loss of moorland fringe habitat. There was some debate about the benefits of forestry plantations for species like Black Grouse. On the one hand, the Forestry Commission was said to recommend planting large areas of Sitka Spruce to encourage grouse production and one scientific workshop group highlighted a study showing that afforestation with native deciduous trees can positively impact on Black Grouse.

It was agreed by some local and scientific knowledge participants that young forests can benefit diverse species, including grouse, in certain areas but only until the canopy closes when studies show that grouse avoid forestry. Red Fox was identified as one of several predator species (e.g. Buzzard, Goshawk) which significantly benefit from monoculture plantation management practices “*...the Forestry Commission stopped killing them [Red Fox] because they ate the stuff that ate the trees*” (LK#5).

However, the negative impacts for ground-nesting birds of developing forestry plantations across the Scottish landscape were summed up as follows: “*Extensive commercial afforestation in the*

Southern Uplands has destroyed large areas of suitable habitat for a whole range of wild birds, bringing predators onto open hills and fragmenting moorland into small pockets. This has been disastrous, particularly for Black Grouse. In many areas suitable habitat remains, but it is not present in sufficient quantity to support birds on a landscape scale, and a general reluctance to manage heather and upland vegetation near forestry by traditional methods (or often any methods) has meant that these remaining islands are becoming increasingly degraded” (LK#6).

Farming intensification practices

Agricultural intensification was identified by several local and scientific workshop groups as an important driver of ground-nesting bird population decline. Grey Partridge and Lapwing were identified as particularly susceptible among other species. Altered timing of field operations, modern cropping practices (e.g. earlier/more frequent harvests, production of silage in place of hay, reduction in green crops, direct-drilling, mowing, rolling); use of agrochemicals; removal of field margins, hedgerows and stone walls; increased livestock numbers; drainage of wetlands and damp pastures; and modern farming vehicles (e.g. larger/faster, sound-proofed) were described as damaging for ground-nesting and small bird species *“It’s deeply frustrating because even the ground-nesting birds on farmland don’t get a... chance to survive. They’re either cut, they’re rolled or whatever” (LK#3).*

Practices such as leaving stubble over winter, ploughing, hay production, appropriate rush management and some crop planting and fencing strategies were said to locally benefit some species (e.g. Black Grouse, Grey Partridge). One participant highlighted several apparent behaviour changes in wader species attributed to *“human-managed”* environments *“Spread of breeding Oystercatchers along rivers, no doubt helped by improved water quality. Switch by Curlew from estuaries to arable farmland as a primary winter feeding habitat” (LK#4).*

Agrochemicals

Participants from three local knowledge workshop groups criticised the use of agrochemicals in agricultural practices due to the direct negative impacts they can have on food supply for ground-nesting birds (e.g. reducing available insect numbers) and on premature mortality of the birds themselves *“I have witnessed sprays used in agriculture to kill grass fields in the spring, wipe out Curlews, Lapwing and Oystercatchers” (LK#5).*

Muirburn

One local knowledge group discussed the relationship between habitat quality and muirburning practices. When managed pro-actively *“in a piecemeal fashion using correct gamekeeping practices” (LK#3)* burning of heather was said to benefit livestock as well as birds, White Hares and other kinds of wildlife. For example large expanses of tall heather were described as detrimental to species like Capercaillie which need areas to *“dry off”* among other things. Perhaps the most inappropriate technique identified was the burning of tall, aged heather no longer producing seed, which can cause uncontrollable, earth-scorching fires, kill invertebrates and other wildlife and destroy fallen seed, resulting in grass growth rather than heather regeneration.

Climate and weather

A few scientific and local knowledge participants worried about how climate change could detrimentally affect the conservation of some ground-nesting bird populations over the long-term,

for example through loss of suitable habitat (e.g. moorland edge). However, climate change impacts were described as difficult to isolate from other kinds of impacts such as land-use and habitat change or fluctuating predator numbers *"...climate has changed which almost certainly affects the Caper [Capercaillie] but it's very difficult to tease out whether... removing or reducing Pine Marten predation impact would be beneficial to the Caper in the context of the changing climate"* (SK#3). Local knowledge participants also discussed the impacts of variable weather conditions on conservation-management strategies. Weather was said to play *"a bigger part than many of us really understand"* (LK#6) especially in affecting the local breeding success and survival of ground-nesting birds (e.g. Black Grouse, Hen Harrier, Lapwing and Oystercatcher) or in promoting available habitat cover thereby influencing vulnerability to predation.

Wind farms

Participants from one local and one scientific workshop group discussed wind farms in the context of ground-nesting birds *"Scale is important for windfarms. The ability to invest in beneficial land management in mitigation areas may produce a net gain in conservation, while the spread of windfarms adjacent to each other may reduce mitigation opportunities beyond the point of benefit"* (SK#3). It was also suggested that the bird surveys conducted on behalf of wind farm operators may be useful to other stakeholders in terms of information-sharing.

Non-predation animal impacts

Livestock grazing

Participants from two local and two scientific knowledge workshop groups discussed livestock grazing regimes in the context of conserving ground-nesting birds. Both scientific studies and local observations were said to indicate that optimal stocking densities and associated levels of grazing were said to significantly benefit ground-nesting birds by suppressing scrub and woodland spread, maintaining open landscapes preferred by wading bird species and to promote or disturb insects thereby creating food for chicks. However, too low livestock numbers were thought to lead to vegetation becoming inaccessible. Some studies were cited suggesting that upland grazing regimes require sensitive localised management *"...grazing in upland environments has different effects on different species in different places because those species have different preferred vegetation mosaics for nesting and feeding"* (SK#2).

Deer

Two local knowledge groups discussed the potential impacts of deer management on ground-nesting birds. For example, deer control was perceived to influence habitat quality: excluding deer from heather moorland areas was said to benefit Black Grouse, whereas *"too effective"* culling of deer may have resulted in loss of suitable habitat *"...the heather was now that rank and that dense that the Capercaillie couldn't walk through it"* (LK#3). Deer culling and associated carrion availability was also associated with increased congregations of Raven in some areas.

Disease and parasites

Black Grouse and Grey Partridge were described as susceptible to disease (e.g. from parasitic worms) and a couple of local knowledge participants described parasite control as part of their traditional *"three legged stool"* game management strategy involving predator control, habitat

management and parasite control *"You can kill as much vermin as you want, but if your grouse get a disease or worm, they'll all die"* (LK#1).

Disease (e.g. Viral Haemorrhagic Disease) was linked to rabbit population decline potentially *"leading an elevated population of Buzzards to look for alternative food sources"* (LK#6).

Ticks

According to participants from several local knowledge workshop groups, ticks are a significant problem for ground-nesting bird health *"The biggest factor apart from predation affecting all ground-nesting birds is understanding the relation between livestock numbers and tick control in Scotland"* (LK#1). It was suggested that a reduction in deer and sheep numbers, along with compulsory sheep-dipping, has increased undergrowth and optimised conditions for tick survival. An associated problem is unintentional distribution of ticks to new areas by walkers enacting their unrestricted *"right to roam"* across moorland areas.

Other human impacts

Human disturbance

Concern about the increasing impact of recreational disturbance on ground-nesting birds was discussed mainly by local knowledge workshop participants but also by some scientific knowledge participants directly involved in population surveys who have witnessed disturbance events first-hand. Disturbance effects were said to have increased due to open access legislation and may be worse on unmanaged land: *"...anywhere near a population centre you've got a problem... If there's no livestock in the field that place is seen as fair game for exercising their dog. If you've got a dozen pairs of Lapwing nesting... it can be catastrophic..."* (SK#1). Walkers and dogs can inadvertently frighten birds off nests or prevent birds returning to breeding sites.

Disturbance was linked to predation, particularly at breeding times when bold, intelligent species (e.g. corvids) take advantage by predating on unguarded eggs or adopting abandoned nests. Multiple disturbances especially in bad weather was also described as detrimental since fleeing chicks may perish. A lack of scientific evidence about the potential effects of disturbances on ground-nesting birds was suggested as one reason why this issue was not of more importance to scientific knowledge participants.

Other kinds of human disturbance discussed included potential impacts by researchers on study species (e.g. eagles and their chicks) during nest monitoring or bird ringing programs, disturbance of birds by horse riders and mountain- and quad-bikers.

Participants described some other human impacts which they considered to be important, including walkers opening or vandalising traps, and people catching and *"dumping"* urban foxes in rural areas *"It's suffering for the fox and you're just adding to the burden of the rural population"* (LK#6). Population effects on scavenger species such as Red Fox, Magpie and gulls feeding at rubbish tips and the like were also highlighted *"a friend of mine in Essex... shot a town fox last year with 12 cubs inside it. A normal hill fox would probably have about four"* (LK#4).

It was suggested that human activities may also have led to an increase in numbers of domestic cats, while the introduction of *"mink and rats and sometimes martens has been a disaster"* (SK#1).

5.2.1.3 Seminar results

Seminar participants suggested a number of possible reasons why local knowledge holders may have ranked predation as the most important driver of population change in the six prey species.

Predators were more visible than other potential factors and there were considered to be increasing numbers of protected predator species. Predator control was observed to have an immediate effect and may often be the only factor that can be changed, if all possible habitat management is already in place. Their impacts were considered especially deleterious during the breeding season and in areas where prey species were depleted or more vulnerable due to other drivers (e.g. agricultural, forestry or recreational disturbance). Other drivers were considered to be more subtle or long-term.

The issue of scale, not only temporal, but also spatial scale was often mentioned, with local knowledge holders potentially reacting to more local events than scientific knowledge holders. The differences between ways of knowing was highlighted by some, with knowledge on predators by local knowledge holders described by one participant as “*an unblinkered stare*”, as opposed to scientists who were perceived as relying on methods that can tend to underestimate predators, spending less time on the ground, and operating over long research time periods. A number of participants highlighted the paucity of robust scientific studies on predation, and the ambiguous results of existing studies.

Seminar participants stressed the need for more education of the public and liaison with local communities in terms of the effects of disturbance and promotion of responsible and respectful behaviours. A number of reasons were identified which could explain why local knowledge holders may have ranked disturbance higher than scientific knowledge holders. Local knowledge holders may observe disturbance and its effects on a regular basis, over a longer time frame and at a more localised level. Other potential reasons could be a perception on the effects of disturbance based on sensitive species such as Capercaillie, or skewed results based on regional differences in disturbance.

5.2.2 Predator species perceived to drive population change (focal species)

5.2.2.1 Questionnaire results

Local Knowledge group respondents were consistently more likely to consider that the four predators have had a medium to high negative impact on each of the six prey species over last 25 years than Scientific Knowledge group respondents. Likelihood Ratio Chi-Square > 64.5, DF = 5, $P < 0.001$). Across the six prey species, the average number of Local Knowledge respondents who thought that the different predator species have had medium to high negative impacts were: 56% for Buzzard, 70% for Crow, 50% for Raven and 66% for Fox. Equivalent figures for the Scientific Knowledge respondents were 20%, 36%, 17% and 34%.

Scientific Knowledge respondents were more likely to consider that predators have had no impact (average 18% .v. Local Knowledge score of 2%) or that they were uncertain about the impact of predators (SK group 22% .v. LK group 9%) than Local Knowledge respondents. Of the four named predators, both Local and Scientific Knowledge respondents consistently ranked Red Fox and Carrion/Hooded Crow as most important, with some variation between prey species (Figure 20). 23 additional predatory species were named by 57% of respondents as having a significant negative impact on the six species of ground-nesting wild birds (Table 11).

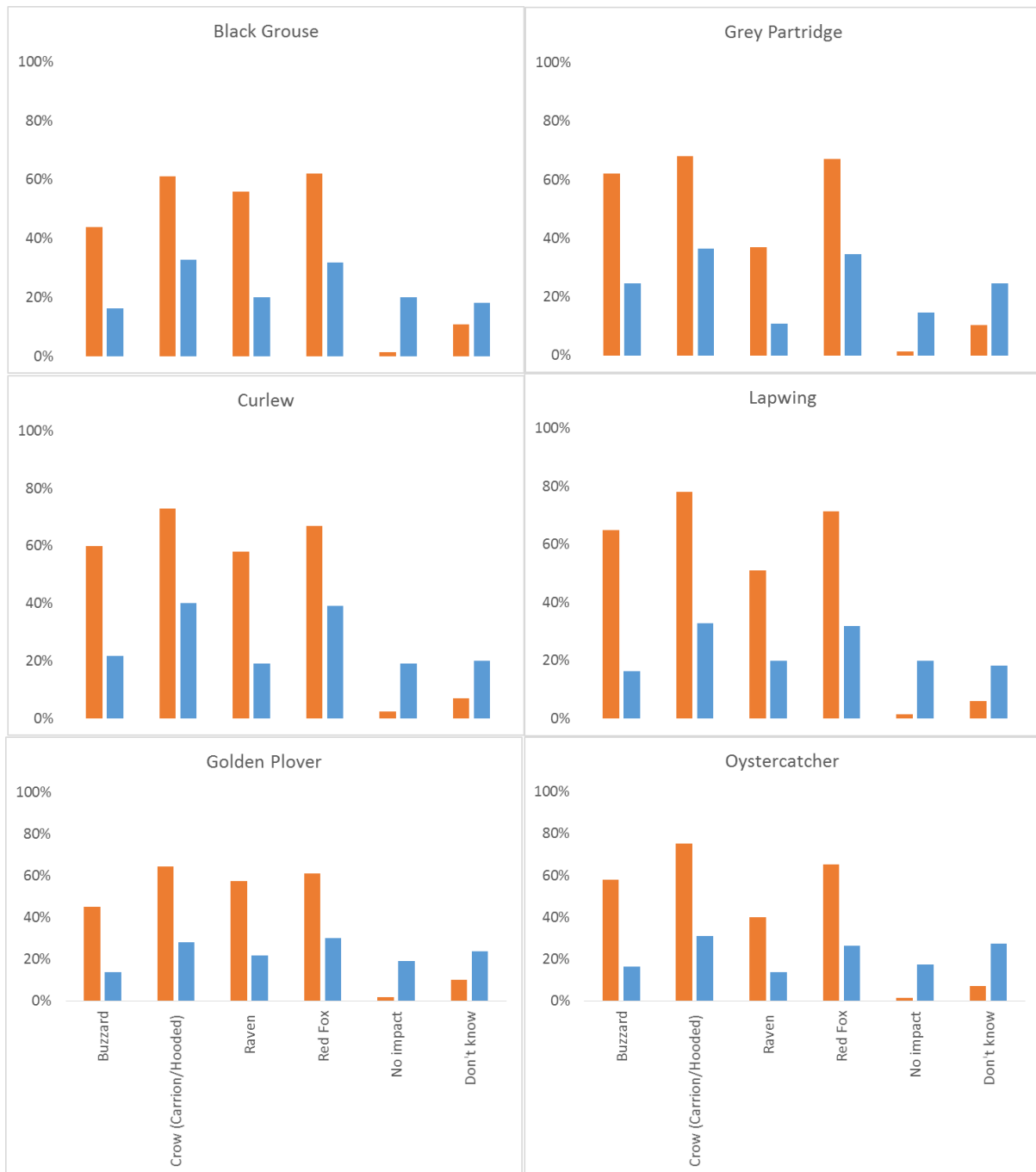


Figure 20. Percentage of Local Knowledge (orange bars) and Scientific Knowledge (blue bars) respondents who identified focal predator species as having had a medium to high negative impact on the different prey species over the last 25 years (n=321).

Table 11. 'Other' predator species perceived to have had a 'significant' (medium to high) negative impact on the six species of ground-nesting wild birds, according to respondents preferring local or scientific knowledge. Showing percentage of respondents preferring local (211 respondents) or scientific knowledge (110 respondents) nominating each species, in order of total number of mentions for all prey species combined. Blank cells indicate a predator species was not nominated by any respondents within a knowledge group. '0%' indicates the predator species was nominated by some respondents within a knowledge group but not perceived to impact upon a particular prey species. Source: questionnaire respondents, n=321.

Prey species													
Predator species	Black Grouse		Curlew		Golden Plover		Grey Partridge		Lapwing		Oystercatcher		Total mentions
	local	scientific	local	scientific	local	scientific	local	scientific	local	scientific	local	scientific	
Crow (Carrion/Hooded)	61%	33%	73%	40%	64%	28%	68%	36%	78%	45%	75%	31%	1127
Red Fox	62%	32%	58%	39%	61%	30%	67%	35%	71%	41%	65%	26%	1060
Buzzard	44%	16%	60%	22%	45%	14%	62%	25%	65%	25%	58%	16%	840
Raven	56%	20%	58%	19%	57%	22%	37%	11%	51%	15%	40%	14%	746
Don't know	11%	18%	7%	20%	10%	24%	10%	25%	6%	18%	7%	27%	255
Stoat/Weasel/Mink	14%	13%	18%	13%	13%	6%	19%	11%	21%	13%	18%	12%	241
Badger	11%	4%	16%	6%	10%	6%	18%	9%	20%	9%	18%	6%	142
No predator impact	1%	20%	2%	19%	2%	19%	1%	15%	1%	16%	1%	17%	138
Pine Marten	18%	6%	10%	2%	8%	3%	7%	2%	8%	3%	7%	2%	119
Gulls	6%	0%	9%	0%	10%	0%	7%	0%	12%	1%	12%	1%	113
Sparrowhawk	4%	1%	6%	1%	7%	2%	13%	3%	10%	4%	8%	1%	92
Goshawk	8%	5%	6%	3%	5%	2%	6%	5%	6%	2%	6%	1%	56

Cat	3%	0%	4%	1%	3%	1%	4%	2%	5%	1%	5%	1%	45
Peregrine Falcon	3%	2%	3%	2%	2%	2%	2%	3%	3%	1%	2%	1%	36
Hen Harrier	3%	2%	2%	1%	3%	1%	2%	0%	2%	0%	2%	0%	31
Red Kite	1%		3%		2%		1%		4%		4%		33
Magpie	0%		2%		1%		3%		3%		3%		26
Jackdaw	0%		2%		1%		2%		3%		3%		22
Otter	1%		2%		1%		1%		2%		2%		23
Humans	1%	1%	1%	1%	1%	1%	1%	2%	1%	1%	1%	1%	11
Birds of Prey	1%		1%		1%		1%		1%		1%		11
Mustelids	1%		1%		1%		1%		1%		1%		17
Hedgehog	0%	0%	0%	1%	0%	1%	0%	0%	2%	3%	1%	2%	16
Rat	0%	1%	0%	1%	0%	1%	1%	1%	1%	1%	1%	1%	9
Rook	0%	1%	0%	1%	0%	1%	0%	1%	0%	1%	0%	1%	8
Arctic/Great Skua		0%		2%		2%		0%		2%		2%	6
Wild Boar		1%		1%		1%		1%		1%		1%	6

5.2.2.2 Workshop results

Each workshop group prioritised the relative importance of the four focal predator species differently, reflecting their diverse knowledge and experiences and the variety of geographic areas with which they are familiar. However, local and scientific knowledge group participants generally agreed that Carrion/Hooded Crow and Red Fox are significant predators of the six focal prey species and a range of other bird and mammal species. There was less consensus about the relative importance of Buzzard and Raven: scientific knowledge participants generally considered these species of lower importance than did local knowledge participants. Raven and Buzzard were considered controversial, partly due to the lack of scientific evidence to measure the extent of their impact on ground-nesting birds and partly because they are protected species and therefore cannot legally be controlled under general licence despite their populations having recovered in recent years. A range of other significant predator species was identified, including: Badger, Pine Marten, Stoat/Weasel/Mink, Sparrowhawk, Goshawk and Peregrine Falcon. These species were sometimes considered more important than some of the focal predators *“Crows, Ravens and Buzzards wipe out most Lapwing eggs/chicks most years in large numbers. Similarly, the odd Peregrine has a devastating impact on a very small Black Grouse population even where visits/kills are relatively infrequent”* (LK#6).

Carrion/Hooded Crow and Red Fox

Based on a combination of scientific evidence and personal observations, all workshop groups agreed that Carrion/Hooded Crow and Red Fox are significant egg predators, causing greatest impact during breeding season. The increasing prevalence of Carrion/Hooded Crow and Red Fox across the country (e.g. due to a combination of their adaptability and reduced predator control) makes these species particularly problematic *“In my study area the density of Carrion Crows is now such that there are flocks of non-breeders, usually c.10 birds but up to 50. These have become a major problem as even Lapwing nesting semi-colonially at high density cannot drive off flocks of crows”* (SK#1).

The fact that Red Fox was said to indiscriminately impact on various prey species all year round, as well as historic cultural associations with crows and foxes as *“vermin”* likely increases their importance in the minds of local and scientific knowledge holders.

Buzzard

Most disagreement about the focal predator species was over the impact of Buzzards on the focal prey species. Seven of the nine workshop groups agreed that large numbers of Buzzards are significantly impacting on various species of ground-nesting birds (e.g. Black Grouse, Curlew, Grey Partridge and Lapwing) as well as other species of birds and mammals. However, some scientific knowledge participants thought they have minimal impact on ground-nesting birds in general and Black Grouse in particular, since studies of their diet and behaviour (e.g. Langholm) indicate that although Buzzards are generalist predators and are known to depredate small numbers of grouse, their main diet is considered to be voles and rabbits.

A small number of scientific knowledge participants expressed concerns about anti-raptor attitudes prevailing among some land managers, which they said can cause conflict between stakeholders. Relatedly, some scientific knowledge participants believed that some local knowledge stakeholders were making a direct link between increasing Buzzard and decreasing ground-nesting bird

populations *“The immediate assumption is because there are more Buzzards around they're the ones eating all the grouse”* (SK#2).

The local knowledge participants believed their observations were well-founded due to their training and experience, leading them to express concerns about the *“sheer numbers”* of Buzzards they see hunting across the landscape *“in all weathers”* and the increasing quantity of prey these Buzzards might require to survive. Several cited personal observations of Buzzard predating some of the focal prey species *“Buzzards are a big problem on partridge and Lapwing. I have seen them taking Lapwing chicks regularly”* (LK#2).

Management of licenced predators (e.g. Carrion/Hooded Crow, Red Fox and Stoat) sometimes meant greater prey availability on managed land which was deemed to attract Buzzards, often at critical times of the year *“We keep the foxes and Stoats down, so the rabbits and hares explode. So that's why we get all the Buzzards... this time of year... when all the crops are up, there's nowhere to feed... when our grouse chicks are small. Everything turning up this time of year has such a huge impact on us”* (LK#1).

Local and scientific knowledge group participants also variously described observations of Buzzard predating: Barn Owl, Capercaillie, Carrion Crow, Hen Harrier, Meadow Pipit, Merlin, Osprey, Pheasant, Red Grouse and small (song) birds; as well as: rabbits, Red Squirrel (a protected species), snakes and voles.

Raven

Both local and scientific knowledge groups considered Ravens to be a significant egg and chick predator of various ground-nesting bird species. Raven numbers were described as having recovered from *“extremely low numbers”* to *“extraordinary levels”* in some areas. Flocking was said to be increasingly problematic due to large congregations of birds and some local and scientific knowledge participants described regularly seeing flocks of 20 non-breeding individuals or more at a time, a behaviour which might not be picked up by breeding bird surveys for example *“Ravens are there for 10 minutes... moving like a set of locusts across the hill in large flocks on prevailing winds”* (LK#5). Increasing Raven numbers were sometimes associated with decreasing crow populations in some places.

Other important predator species

Many other predator species were identified (Table 11), most often by local knowledge participants, as impacting significantly on ground-nesting birds. Badger and Pine Marten and to a certain extent Goshawk and Sparrowhawk were frequently mentioned and considered controversial due to their protected status.

Both local and scientific knowledge participants identified Badger as particularly important because its population is perceived to be expanding at a national level and it is considered a significant, opportunistic predator, mainly of ground-nesting bird eggs and chicks. The Badger was also described as influencing Hedgehog and Red Fox population dynamics and possibly becoming a more important predator of ground-nesting birds than Red Fox. As one participant explained *“...Badgers have taken over the traditional cubbing earths so it's pushed the foxes in to places that you can't find, therefore they're more successful... then instead of actually controlling your fox at the right time, they've had the cubs, the cubs are big and they come and scoff the birds”* (SK#3). Other Badger

impacts mentioned included: digging up woodland habitat for Lapwing and Merlin; predating bee and wasp nests; and killing lambs.

6. CONSERVATION-MANAGEMENT OPTIONS

6.1 Natural science review of conservation-management options

PREDATOR MANAGEMENT

Predator removal

Unless explicitly stated, consideration of predator removal in this report focuses exclusively on (lethal) predator control. This involves removing predators by killing them, and is one of the commonest forms of predator management practiced and studied. While the implications for prey are usually similar to those of non-lethal removal, predator control typically requires much less time, money and effort, and is therefore much more efficient.

There have been several systematic reviews which have quantified the effectiveness of predator removal for increasing the breeding success or population density of prey species (Cote and Sutherland, 1997; Holt et al., 2008; Newton, 1998; Salo et al., 2007; Smith, 2000). Earlier reviews such as Côté & Sutherland (1997) showed that predator removal could increase the breeding success and post-breeding densities of bird populations. However, their review of 20 studies did not find any longer last effects of predator control (i.e. effects on breeding densities). In contrast, a review of predator removal studies by Newton (1998) showed that, in more than half of the studies where the relevant parameters were measured, increased post-breeding numbers did translate to increases in breeding numbers in subsequent years. Since then, an increase in the number of predator removal studies has enabled researchers to confirm that predator control can also increase breeding populations in some prey species, and that this seems to be true for both endangered and common prey species (Holt et al., 2008; Roos et al., 2012; Smith et al., 2010). Studies in the UK indicate that most types of predator control are likely to benefit ground-nesting birds, in particular waders and gamebirds, whereas song birds, and birds nesting in trees and shrubs, are less likely to benefit (Fuller et al., 2005; Gibbons et al., 2007; Roos et al., 2012). However, in other parts of the world it appears that benefits of predator management can also accrue to arboreal nesters, due to the increased importance of predation by snakes and climbing mammals (Roos et al., 2012; Smith et al., 2010).

In a review carried out by Smith (2000), only 5 controlled experiments of predator control on gamebirds were found in Europe. Three reported increased breeding success, four reported that breeding numbers increased and two found significant increases in the size of subsequent year breeding populations. The review also identified a large number of correlative studies in Britain that suggested that legal control of predators increases upland bird populations.

Control of a particular predator species most often takes place in the context of a suite of other activities. These typically include the control of other predator species, and frequently also include other activities including habitat maintenance, alteration or enhancement, and improvement of food supply. Unless some attempt is made to partition these different activities out across either time or space, it is not usually possible to ascribe effects observed by studies of predator control to any one particular activity. This can lead to the masking of relevant relationships and the emergence of

misleading ones. For example, Beja et al. (2009) examine abundance of predator and prey species in relation to various aspects of game management, and find that some measures of game management intensity are negatively related to predator abundance (presumably due to predator control), whereas others are positively related (presumably because the positive effects of elevated prey densities over-ride the negative impacts of predator control for these species). Where there are studies that provide clear evidence for the effectiveness of a particular type of control, we have focussed our attention on these. Where such clear evidence is lacking, we have extracted what evidence is available from the literature, while highlighting the uncertainty that must accompany their interpretation.

The effectiveness of predator reduction will be greatly influenced by the methods employed and the time of year it is carried out; removal of predators during the breeding season when individuals are territorial is most likely to result in greater population reductions (Reynolds & Tapper 1996). Even where predation is thought to be a factor limiting the breeding success or population density of prey populations, removal of predators may not necessarily have the desired effect of increasing prey abundance (Cote and Sutherland, 1997). This may be due to increased populations of “meso-predators” (smaller predators whose abundance and predation rates increase following removal of apex predators; Crooks & Soule 1999), with the net result that the predator removal attempt is not effective, or less effective than might be supposed through calculations of their impact on prey species. In general, control programmes removing multiple predators are more effective than those focussed on single species, probably as a result of reducing the opportunity for compensatory predation (Cote and Sutherland, 1997; Holt et al., 2008; Smith et al., 2010).

Mammalian predator removal

Removal of mammalian predators has been described as being more effective than control programmes targeting avian species (Holt et al. 2008), and removal of alien predators more effective than control of native species (Salo et al. 2007; Holt et al. 2008). There are some limitations in interpreting such comparisons, however, as alien predators included in these reviews were also all mammalian, and many of the bird removal studies reviewed did not control mammals, making it possible that mammalian predation rates could have increased (Holt et al. 2008). A review of American studies noted that mammalian predator control may also lead to increases in alternative predators (Woodroffe and Redpath, 2015).

Several of the mammal species covered in this review are protected, or partially protected from killing or disturbance by the Wildlife & Countryside Act 1981 (as amended; referred to here as the “Act”), the primary legislation which protects animals in the United Kingdom; following devolution there are differences between the constituent countries that comprise the UK, although for the species we consider in this section the protection afforded and restrictions on lethal control is broadly similar. Some species also have additional protection either at the UK (e.g. Protection of Badgers Act 1992) or EU level (Habitats Directive 1994). Whilst it is possible to apply to the statutory authorities for a licence to remove individual animals, they are only granted in exceptional circumstances and are subject to strict criteria. Consequently here we focus on studies which have examined control of Brown Rat, Red Fox, Stoat, Weasel, Ferret and American Mink for the purposes of conserving bird populations.

Scale

The scale of a predator control programme can greatly influence its effectiveness. Reviewing bird predation by and control of American Mink populations, Sugoto et al. (2009) found that control programmes were more likely to be effective if operating to reduce populations over large areas, rather than eliminating mink from discrete sites, except in the case of islands. However, the effectiveness of different culling intensities will depend on individual circumstances. Smith et al. (2010) noted that since the majority of studies did not report on predator densities before and after control measures, they were unable to examine the extent to which predator populations had been reduced, an important consideration in the planning of any control programme. The lack of effect of intensive gull culling on the Isle of May (Harris and Wanless, 1997) contrasts with the effectiveness of intensive and localised control of mainland mink populations for 2-3 months each year during the spring and early summer, which proved sufficient to mitigate the impact of mink predation on the productivity of tern colonies (Craik, 1998). A ten year programme of conservation management, including predator control, had little or no impact on populations of moorland birds (Calladine et al., 2014b). It is likely that this was due to a failure of predator control to sufficiently reduce the numbers of predators. Although it is likely that the original programme of management was appropriate to conditions at the time it was put together, subsequent reductions in the levels of predator control on the surrounding land during the course of the study undermined the effectiveness of predator control on the study site. This highlights the need for ongoing monitoring to assess the efficacy of management, and for management prescriptions to be responsive to changing circumstances (Calladine et al., 2014b).

Predator densities

Pre-control predator densities may also influence the effectiveness of predator control strategies. Bolton et al. (2007) found that control programmes that were successful in reducing densities of Red Fox and Carrion Crow by a factor of two had no significant effect on Lapwing numbers, except in areas where pre-control predator densities were highest. This may be, at least in part, because of effects of predation tend to be positively related to predator density (Eglington et al., 2008), such that there is greater potential for a programme of control to have an effect when there are many predators. However, many types of predator control demand greater levels of effort at low predator densities than would be needed at high predator densities to achieve comparable effects (e.g. Bester and Skinner, 1991).

Interaction between control and other management types

Parrott (2015) identified several measures that could be taken to mitigate against losses of pen-reared Pheasant poults to Buzzards and other raptors, including increasing age and decreasing group size of stocked/released poults, minimising perching opportunities for Buzzards, providing cover for poults, use of scaring devices at pens, and diversionary feeding. However, insufficient field evidence currently exists to evaluate the effectiveness of most of these measures.

Corvid control

Control of crows is typically carried out as part of a suite of predator control activities aimed at reducing the abundance and impact of several predator species, including Red Fox, mustelids, and gulls. Bodey et al. (2009) reported that experimental reduction of Hooded Crow numbers was followed by increases in size of Raven population, and in the proportion of artificial eggs taken by corvids. Removal of Hooded Crow from two Eider island colonies increased population growth in one colony but not in the other.

Mixed species predator control that affected Carrion Crow abundance more than other predators successfully increased Black Grouse and Red Grouse productivity but may have benefitted from the mixed-species predator control preventing increases in other predators (Summers et al., 2004; Fletcher et al., 2013). See the [Black Grouse](#) and [Upland gamebird](#) sections for more information). In a review of the impacts of corvids on bird populations and abundance (Madden et al., 2015), no effect of corvids on either abundance or productivity of prey species was found in 81% of studies. Negative impacts were found more often on productivity than abundance and crows had more negative impacts than Magpies. Experiments that removed only corvids were less likely to be beneficial than experiments that removed corvids and other predators (Madden et al., 2015).

Gull control

Control of gull populations has sometimes been unsuccessful in achieving increases in population growth of prey species, even in cases where gull populations were reduced to a fraction of their former levels. On the Isle of May, Fife, intensive culls that succeed in reducing and maintaining numbers of large gulls at less than a quarter of their previous size failed to reduce predation to a level that allowed Oystercatcher productivity to increase (Harris and Wanless, 1997).

Raptor control

Although raptors are afforded legal protection in most countries in Europe, several studies have provided evidence that their numbers are, in many areas, limited by illegal population control (see Drivers: Predators – Other human impacts). In some cases this evidence is not sufficient to discern the methods by which this control is achieved, but in other cases it is possible to identify effects of management on raptor productivity, survival, or both. Grouse moor management has been associated with impacts on raptor breeding success and site occupancy for Peregrine (Amar et al., 2012; North East Scotland Raptor Study Group, 2015), Hen Harrier (Etheridge et al., 1997; Fielding et al., 2011; Hayhow et al., 2013) and Golden Eagle (Fielding and Haworth, 2014; Whitfield et al., 2004b). There is little research on raptor control outside of Britain, possibly indicating the higher prevalence of raptor persecution in Britain compared to elsewhere in Europe. Lees et al. (2013) used a simulation approach to determine possible impacts of Buzzard control on pheasant populations. They concluded that Buzzard control could lead to an increase in other mesopredators and have little impact on pheasant mortality.

Red Fox control

Culling Foxes is widespread in the UK and is used to reduce predation on domestic livestock, poultry, reared and wild game, other wildlife, and the spread of disease. Before the Hunting Act (2004) it was also a common sporting pursuit (Heydon & Reynolds, 2000a). Whilst many studies report success in the reduction of Fox populations at a local scale (e.g. Reynolds et al., 1993; Tapper et al., 1996), in other studies there was no apparent effect of Fox control on subsequent abundance (e.g. Summers et al., 2004). The extent to which culling can impact on Fox populations at a larger scale, however, is the subject of some debate (e.g. Hewson, 1986; Heydon and Reynolds, 2000b; Baker et al., 2002; Aebischer et al., 2003). Using an individual-based, spatially-explicit population model to examine the efficacy of different control methods, Rushton et al., (2006) concluded that culling at the den during the breeding period was the most effective way of suppressing Fox populations. In contrast, the model indicated that removal of Foxes over winter was relatively ineffective, a result in-line with several empirical studies; it has been suggested that the underlying reason for this is that it simply removes individuals that would have died in any case, and numbers in spring will be enhanced by immigration from surrounding areas (Hewson 1986; Reynolds 2002; Baker & Harris 2006). However, whilst Lieury et al., (2015) found strong compensatory density feedback acting through immigration as previously suggested, they suggested that culling in winter was more effective and required a lower culling rate, than in other seasons.

Several studies have demonstrated substantial reductions in Fox populations as part of experiments to test the effect on a variety of bird species (primarily waders and gamebirds) although in some studies this reduction was very variable between sites (Tapper et al., 1996; Bolton et al., 2007; Fletcher et al., 2010, 2013; Mateo-Moriones et al., 2012). The effect of control can also be cumulative over time, both on the reduction in Fox population achieved (Bolton et al., 2007), and the positive response from bird populations (Tapper et al., 1996). However, in one study Red Grouse populations initially increased in response to predator control but subsequently declined while control continued (Fletcher et al., 2013). In Fletcher et al., (2010) and Tapper et al., (1996), improvements in both breeding success and population densities of ground-nesting birds in response to predator control were observed (see section 7). Hen Harrier clutch survival and productivity at Langholm estate were higher when it was kept (Baines and Richardson, 2013). Predation by foxes was the most frequent cause of Hen Harrier nest failure. Such differences between studies may be related to the range of predator species targeted and the degree of philopatry between prey species (Bolton et al., 2007).

Brown Rat and Black Rat control

Worldwide, a number of rat species have been deliberately or unintentionally introduced outside of their native range and there is compelling evidence of the negative effects that such introductions can exert on populations of wide variety of native species (Townsend et al., 2006). Rat control typically involves the use of poisoned bait delivered via bait stations, which can be an issue where non-target species, also vulnerable to the poison are present. A large number of rat eradication projects, primarily on offshore islands have demonstrated positive responses of wildlife (Townsend et al., 2006). Two island eradications of Black Rats in Europe (Azores – Portugal, Amaral et al., 2010; Lundy – England, Lock, 2006) showed that some species of breeding seabirds, largely eliminated due to predation by rats of eggs and chicks, quickly returned to breed once rats had been removed. Several

seabird species on Canna (Scotland) have continued to decline even after the removal of Brown Rats, presumably because of other factors (such as the decline in food availability and changes in climate), highlighting that removal of even a major predator does not always lead to population increases in prey populations (Swann, 2006).

Stoat and Weasel control

Stoats and Weasels are regularly killed either by trapping or shooting by gamekeepers to increase gamebird populations (McDonald & Murphy, 1999). Whilst we did find one study that had attempted to control Stoat and Weasel populations for the purposes of enhancing bird populations in the UK (Fletcher et al., 2010), the mustelid populations were already low and control ineffective, though abundance of small mustelids was related to variation in over-summer adult survival of Red Grouse (Fletcher et al., 2013). Removal of Weasels in Finland resulted in short-term increases in populations of small birds but no change in gamebirds (Nordahl & Korpimäki, 2000).

Polecat and Ferret control

Whilst a licence is required to trap Polecats, Morris (1993) suggested that this control method was regularly used illegally, a situation made more problematic by the similarity with Ferrets and Ferret/Polecat hybrids, which may be legally killed without licence. A survey in 1996 indicated that Polecats are viewed as a relatively minor pest by farmers and gamekeepers in comparison to Fox and Stoats, but this may be in part related to their current relative scarcity (Packer & Birks 1999). An experiment to test the effects of Ferrets on Lapwing populations successfully reduced their population density prior to the onset of the birds' breeding season, however, there was no increase in breeding success suggesting that they were not a limiting factor in this population (Bodey et al., 2011). As part of the American Mink eradication on the Western Isles (Scotland), introduced Ferrets and Brown Rats were also killed; long term monitoring of tern populations indicated improvements in hatching success where the three mammalian predators were removed (SNH, 2006).

American Mink control

Across Europe there are many control programmes to reduce the negative impact that introduced American Mink exert on populations of ground-nesting birds, Water Voles, and the European Mink (e.g. Craik, 1998; Roy, 2006; Banks et al., 2009; Reynolds et al., 2013). Notable successes in reducing or eradicating Mink populations include the Hebridean Mink Project (Roy, 2006), removal at seabird colonies along the west coast of Scotland (Craik 1998), the Scottish Mink Initiative which operates across large parts of northern Scotland, a series of culls in Spain and Catalonia (Melero et al., 2010), and a long-term programme in the Baltic sea archipelago (e.g. Banks et al., 2009). However, since Mink can move back into cleared areas and are good swimmers all of these examples, with the exception of the Hebridean Mink Project, represent long-term control programmes to reduce populations and limit spread, rather than eradication projects.

Innovations such as the use of rafts to monitor Mink presence, have facilitated volunteer engagement and require substantially less effort than trapping when Mink populations reach low levels (e.g. Reynolds et al., 2013). Overall responses from the bird populations of concern following removal have been positive; for example, tern colonies across the Western Isles are now more

widely distributed and breeding success has increased (Roy, 2006), and there were increases in breeding populations of 14/22 seabird species in the Baltic sea archipelago (Nordstrom et al., 2002, 2003, 2004; Banks et al., 2009). Even where complete eradication is not possible, targeted removal of Mink at critical times of year have resulted in recolonisation of former sites and population increases (e.g. Craik, 1998). There are, however, variations in bird responses which are likely to be related to how vulnerable they are from mink predation (e.g. Ratcliffe et al., 2006, 2008), and that the time required for recovery can vary between species (Banks et al., 2009). In an experiment in Latvia, Opermanis et al., (2005) report that Mink removal correlated positively with levels of depredation from Marsh Harrier on duck nests and suggested that reduced Mink predation was being compensated for by increase harrier predation.

Mixed species control

In a management context, the majority of predator control programmes target multiple species of predator. One of the reasons for this is that, in many cases, single species control programmes would be much less effective than multiple species ones. This isn't just because single species control leaves predation by other species unchanged. In many cases, other predators respond to the removal of a competitor by changing at least a component of their diet to exploit the prey items that aren't being used by the removed predator. Parish et al. (2007) showed that wild Grey Partridge mortality, most commonly caused by predation, was not affected by an experimental programme of generalist predator control because of increases in compensatory predation by raptors such as Sparrowhawks and Buzzards. In the same study, predator control was found to benefit captive-reared birds, which had much higher mortality from foxes than wild birds in the areas with and without predator control.

Many studies of predator control have made use of past or existing variation in predator control regimes to investigate the effect that these have had on prey populations, and several other large, experimental studies have implemented multi-species programmes of control in order to test the effects of realistic management regimes. Such approaches have yielded useful information about the range of effects that predator control management can achieve, but often do not allow the effects of different predator species to be distinguished from one another. There are also a number of studies that examine the impact of mixed-species predator control combined with habitat management. In particular, many studies examine the impact of grouse moor management and these are reviewed in [the section on moorland game management](#).

Most mixed-species predator control experiments in Britain have included control of Red Foxes and corvids but mustelids such as Stoats and Weasels are also commonly controlled. The majority of mixed-species predator control studies have examined impacts on waders. Control of Red Foxes and corvids has been found to increase Lapwing nest survival in lowland wet grassland but only where there were high background densities of Red Foxes and crows (Bolton et al., 2007). There was some evidence that Lapwing populations also increased but the findings were not conclusive (see [Lapwing section](#) for more detail). At Langholm in southern Scotland, a cessation of gamekeeping in 2000 led to increases in Carrion Crows and Red Foxes and a subsequent decline in breeding Lapwing pairs from 0.38 to 0.01 per km² (Baines et al., 2008). Other controlled predators such as mustelids were not monitored so their impacts on Lapwings cannot be inferred. However, Lapwing numbers did not recover after predator control was reinitiated in 2007 (Langholm Moor Demonstration Project,

2014) see the [Lapwing section](#) for more detail. The reasons for the failure of predation control where it previously increased Lapwing populations are unknown but the results indicate that the effectiveness of predator control is influenced by other factors. Following experimental reductions in Red Fox and Carrion Crow abundance at Otterburn in Northern England, in conjunction with removal of Stoats and Weasels, the breeding success of both Curlew and Golden Plover showed large increases (Fletcher et al. 2010, see [Curlew drivers](#) section for most detail and [Golden Plover](#) section for additional detail). The population density of Curlew and Golden plover also increased in this example, although the variation in population growth was high.

There are also a number of studies that examine the impact of predator control on gamebirds. Predator control can be used to increase Grey Partridge populations and may be effective if carried out only during the breeding season (Game Conservancy Trust, 2005). Marcstrom et al. (1988) found that removal of both Red Foxes and Pine Martens on Swedish islands, positively affected both the proportion of hens with broods, and average brood size across four grouse species: Capercaillie, Black Grouse, Hazel Grouse and Red Grouse (see the [Black Grouse](#) section for more detail). Control of Red Foxes and Carrion Crows at Abernethy Forest in Scotland, lead to increases in Black Grouse productivity, despite no observed decline in fox density (Summers et al., 2004). There was some evidence that control of Red Fox and corvids (when carried out in conjunction with control of other mammals) increased Grey Partridge populations in Hungary (Farago et al. 2012). However, predation control was measured only by number of predators killed, with no reference to predator abundance, making the effect of predator management difficult to prove. In a review by Newton (1998), he found that Red Grouse populations were higher on moors where predator control had been carried out in conjunction with habitat management but Black Grouse populations were not.

There is little research on the impacts of mixed predator control on other species. An experimental study in England found that mixed species predator control was related both to productivity and to breeding densities of Blackbird (White et al., 2008). The benefits of predator control in this study, particularly to other breeding songbird species, increased with the rigour and taxonomic breadth of control programmes (White et al., 2014).

In some cases, predator control failed to increase target species' populations, due to compensating predation by non-controlled predators. Control of Carrion Crow and Common Gull on a Scottish moorland resulted in increased hatching rates of several species of wader, including Curlew and Lapwing (though not Golden Plover) (Parr, 1993), However, it was not successful in boosting breeding wader populations, possibly because of continued and increasing predation by other predator species, including Red Fox. Parker (1984) found that removal of all breeding and most non-breeding corvids resulted in slight increases in nest survival in Red Grouse and Black Grouse in Norway, but this did not translate into increased productivity due to compensatory increases in predation by Stoats. An experimental study on Rathlin island, Northern Ireland aimed to test the effects of Ferrets and Hooded Crows on the declining Lapwing population (Bodey et al., 2011). There was little apparent effect of reduced predator abundance on Lapwing breeding success, possibly due to increases in Ravens, which were not controlled.

Predator exclusion

Preventing predators from accessing their prey, particularly during periods when prey individuals are relatively immobile, such as during nesting, can be an effective means of alleviating the effects of predation on prey populations. This strategy applies principally to prevention of mammalian predation, it being typically more difficult to exclude avian predators (at least from eggs and young of medium-sized birds such as waders and gamebirds) without seriously compromising the movements of the target prey species. However, Morrison & Gurney (2007) report a successful attempt to reduce gull predation by deploying artificial enclosures around nests of Roseate Terns.

A meta-analysis of the efficacy of excluding nest predators for protecting bird populations showed that the use of fences or nest cages increased hatching success by an average of 94% (Smith et al. 2011). Of predator-prey interactions being considered in this review, we found four studies which had examined the use of fencing to reduce predation of waders, either by introduced Hedgehogs (Jackson 2001), or Foxes (Rickenbach et al. 2011; Malpas et al. 2013a; Degen 2008). In Jackson 2001, fences were used to test whether Hedgehog predation was likely to be a contributory factor in the decline of several wader populations; the probability of nest failure was 2.4 fold (95% confidence Intervals 1.2 – 5.0) higher outside fenced plots than those within fences. The efficacy of excluding mammalian predators on Lapwing breeding success, as opposed to lethal control has been tested in two studies, one each in the UK and Switzerland (Rickenbach et al. 2011; Malpas et al. 2013a). In Malpas et al. (2013a), electric exclusion fences, designed to keep out relatively large mammals such as Foxes and Badgers, resulted in a three to four-fold increase in nest survival and productivity with the numbers of chicks fledged per pair rising from 0.23 (± 0.07 SE) to 0.79 ($+0.14/-0.13$ SE) when fences were used. Focussing on the possible benefits of fencing for chick survival, Rickenbach et al. 2011 showed that overnight estimates of survival for chicks located within enclosures was far greater than those of chicks outside enclosures; model estimates (assuming chicks lived from hatching to fledging either entirely inside or outside enclosures; in reality they were able to move between areas) indicated 24% of chicks inside fences survived to fledging, whilst no chicks outside fences survived. Degen et al. (2008) describe the conservation programme put in place to improve the prospects of a small and vulnerable population of Golden Plovers in Germany. Breeding success in this population was low, mostly due to Red Fox predation and peat extraction operations. After four years of nest protection (using electric fences, olfactory deterrence and a night-time guard), nest numbers, along with survival of eggs and chicks, increased.

There are limitations with both fencing and nest cages, however. Fences can typically only be used for relatively small areas and can be costly to install and maintain, particularly for electrified fences. Rabbit burrows reduced the effectiveness of fences to exclude Hedgehogs on the Uists highlighting the need for regular inspections (Jackson 2001). The potential for bird collisions and the restriction of movement for young birds must also be considered. Fences are also ineffective against avian predators who, in some cases, have increased predation rates once mammalian predators have been excluded (Gibbons et al. 2007). The positioning of nest cages can cause disturbance to incubating birds and may also lead to increased predation, particularly for species that are slow to flush (e.g. Isaksson et al. 2007). Predation of Lapwing and Redshank eggs by mammalian and avian predators was reduced by placing cages over nests. However, for Redshank, a species that is slow to flush, adult predation increased where the protective cages were used because of the additional time required to escape (Isaksson et al., 2007).

Diversionsary feeding

Amar et al. (2004) found that diversionsary feeding of breeding Hen Harriers reduced their intake of Red Grouse to almost negligible levels. One of the few studies to address the effect of diversionsary feeding on predator impact (Thompson et al., 2009) found that it successfully reduced the number of Red Grouse chicks taken by breeding Hen Harriers, but that this did not translate in an increase in the numbers of adult Red Grouse available for shooting. A modelling study by New et al. (2012) concluded that, in isolation, diversionsary feeding is unlikely to be very effective at mitigating against the effects of Hen Harrier predation on Red Grouse breeding productivity. Hen Harrier predation did not decline enough as a result of diversionsary feeding to suppress grouse population cycles. The authors of this study also point out that whether, and to what extent, diversionsary feeding increases the potential for Hen Harrier populations to impact on Red Grouse by increasing the productivity or survival of Hen Harriers is not well understood. Diversionsary feeding has also been successfully used in the UK to decrease predation by Kestrels on Little Tern eggs and chicks (Roos et al., 2012; Smart and Ratcliffe, 2000).

Other strategies to reduce predation

There is considerable interest in whether ecosystem restoration, through the re-establishment of top predators or competitors can play a role in mitigating impacts from native or non-native predators. In the context of this review, we found studies examining relationships between American Mink, Otters and White-tailed Sea Eagles, and Pine Martens and Grey Squirrels. It has been suggested that the recovery of Otter populations throughout much of their UK range has contributed to recent declines of American Mink (see [section 4](#)) through intraspecific competition (Bonesi & Macdonald 2004; Bonesi et al. 2006). The most direct evidence of this was a release of captive-bred Otters into the Upper Thames catchment in England (Bonesi & Macdonald 2004); at three release sites occupancy by mink decreased by 23-77%, whilst at a control sites levels remained the same. Similarly, a study examining the relative predation risk from White-tailed Sea Eagles in the Baltic sea archipelago found that mink reduced the distance they would swim between islands in areas of higher eagle density (Salo et al. 2007). Whether this behavioural modification is likely to result in reduced population growth is unknown, however. Sheehy et al. (2014) have suggested that recolonisation of their former range by Pine Martens is linked to declines in Grey Squirrel in the Irish midlands. Whilst great care is needed in the interpretation of such correlative studies, they may indicate fruitful avenues for future experimental research. A similar observational study in southern Sweden found strong relationships between changes in fox population and changes in abundance of American Mink (Carlsson et al., 2010).

Another approach which may prove useful in enabling managers to reduce levels of predation on wild birds is conditioned taste aversion. This technique relies on conditioning predators to avoid predating the eggs of some or all wild birds by treating real or model eggs with noxious chemicals that make animals that ingest them sick and/or that taste repellent. Although the efficacy of this technique in conditioning foxes and badgers against eating artificial baits has been demonstrated in Britain (Baker et al., 2007), it has yet to be proven as a means of decreasing levels of predation experienced by wild birds in the UK. However, at least one study in Australia has shown that conditioned taste aversion can be successfully used to reduce levels of fox predation on breeding terns (Maguire et al., 2009). Particularly in situations where it is not possible or desirable to address

predation by killing, removing or excluding predators, could be used to increasing productivity of ground-nesting birds. However, more research is needed to inform managers about how best to use this technique.

There is an increasing literature suggesting that predation from domestic cats is likely to pose a risk to a wide variety of wildlife species through direct predation (e.g. Baker et al. 2008; Thomas et al. 2012) and potentially through behavioural modification in response to predation risk (Beckerman et al. 2007). The use of belled collars can decrease returns of birds and mammals caught by cats by between 38% - 61% (Ruxton et al. 2002; Nelson et al. 2005; Gordon et al. 2010). However, surveys have indicated that many cat owners reject the evidence that cats are a threat to wildlife and oppose current potential mitigation strategies, including the use of collars (McDonald et al. 2015).

HABITAT AND FOOD SUPPLY

Control of grazer densities and mowing

Control of grazer densities is used as a conservation management option most commonly in the uplands and on wet grassland (Newton, 2004; Eglington, 2009). Benefits of a reduction in grazing density can be mediated through a reduced risk of trampling during the nesting period, a reduction in predation risk (MacDonald, 2006; Eglington, 2009) and an increase in invertebrate food availability (Beintema *et al.* 1990). Mowing affects birds through similar mechanisms and is also controlled as a conservation management option under some circumstances.

Uplands: Red Grouse density and breeding success increased in Irish blanket bog after low heather coverage was increased by fertilising heather or removing grazers (Watson and O'Hare, 1979). Black Grouse abundance and breeding success was also higher where sward height was increased by reduced grazing (Newton, 2004), irrespective of whether the area was managed by gamekeepers (Baines, 1996). Calladine *et al.* (2002) found higher abundances and breeding success of Black Grouse at sites with <1.1 sheep ha⁻¹ in summer and <0.5 sheep ha⁻¹ in winter compared to sites with sheep densities two and three times higher respectively in the summer and winter. An increase in a Black Grouse populations in the north of England increased temporarily after grazing was restricted to summer months only and at densities of <1 sheep ha⁻¹ (Warren and Baines, 2004). However, populations declined after 5-7 years, probably because the sward height got too high (Warren and Baines, 2004). Reduction in deer populations and low-intensity cattle grazing can both increase Black Grouse populations (Malkova and Prochazka, 2003). Grazing management to increase habitat heterogeneity is likely to benefit Black Grouse (Immitzer *et al.*, 2014). Snipe were also benefitted by a reduction in grazing (O'Brien and Wilson, 2011). Mowing and burning increased the abundance of bilberries and spiders, two important food sources for Capercaillie, leading to an increase in Capercaillie (Hancock *et al.*, 2011).

Wet grassland: Many wader species are benefitted by the control of grazing and mowing and moderate grazing may be optimal for many wader populations (Sabatier *et al.*, 2012).. A review of agricultural wet grassland management for waders identified the grazing management as particularly important (Durant *et al.*, 2008). Mortality of waders by trampling is common and can influence populations (Chamberlain and Fuller, 2000; O'Brien and Wilson, 2011). As pointed out by Newton (2013), an important aspect of nest destruction by livestock trampling (or crushing with

agricultural machinery) is that, unlike drivers such as food availability or (most types of) predation, rates of nest loss tend to be independent of population density. This means that, in areas and habitats where losses to non-predatory nest destruction are high, it can quickly result in regional and land-use-specific extinctions. Corncrake population increases have been seen in areas with conservation management schemes that include delayed mowing or grazing (O'Brien et al., 2006), in order to enable breeding birds to escape the ecological trap described by Green et al. (1997). Lapwings, Redshank and Snipe in Scotland benefitted, although only moderately, from grassland management options that limited grazing and other agricultural activity during wader breeding season (O'Brien and Wilson, 2011). Mowing ditch-sides increased Common Sandpiper abundance in Estonia (Eglington, 2009).

Woodland: In woodland, management to exclude deer led to an increase in understorey birds including several declining migrant species (Gill and Fuller, 2007; Martin et al., 2011).

Establishment of crops or vegetation

For many bird species, particularly farmland birds, food availability is likely to limit their populations. For example, between 25% and 50% of farmland bird populations are predicted to decline due to the loss of set-aside, probably because of a decline in food availability (Gillings et al., 2010). Options that increase food availability can also increase nesting cover (O'Brien et al., 2006). Options include providing changing to mixed cropping regimes, increasing winter food through providing areas such as winter wild bird crops (Gillings et al., 2010) and other winter foraging habitats, and increasing breeding season food and cover with options for field margins such as beetle banks (Thomas et al., 2001), Conservation Headlands (Newton, 2004a) and mixed wildlife cover strips (Bro et al., 2004).

Measures aimed at increasing the availability of winter food have had broadly positive results. Farmland bird densities were higher in winter wild bird crops than on set-aside land or any crop types (Gillings et al., 2010) and Sage et al. (2005) found that winter crops planted for gamebirds increased the populations of many songbird species. Davey et al. (2010b) found that winter foraging options in England did not benefit most of the species they were aimed at, but this study was based on data collected just a few years after the relevant agri-environment schemes were started. A subsequent study (Baker et al., 2012) indicated that stubble management options positively affected winter populations of several bird species, including species that were experiencing declines at a national level. In lowland England, Hinsley et al. (2010) showed that the provision of winter food (in the form of seed crop mixtures) resulted in increased abundance of birds in both winter and in the following breeding season.

The provision of food and cover in the breeding season has had mixed results. The increase of oilseed rape is likely to have provided additional food and nesting habitat for a range of species including Linnet and Reed Bunting (Newton, 2004). Corncrake increases were associated with the creation or management of early and late cover (O'Brien et al., 2006) and beetle banks were found to provide considerable quantities of nesting cover for adults and chick-food, although at lower densities than conventional margins (Thomas et al., 2001). Agri-environmental options such as Conservation Headlands can effectively increase invertebrate abundance, increase Grey Partridge chick survival and can be used to increase nesting habitat (Newton, 2004a). Grey Partridge breeding success increased where grassy strips containing abundant dead grass were provided (Sotherton et

al., 2014). However, wildlife cover strips of maize or kale-based mixtures in France did not improve reproductive success of Grey Partridges and were associated with higher winter mortality, possibly because they provided better hunting cover for predators (Bro et al., 2004). Soil scarification increased the abundance of invertebrate and seed feeders but the positive effects were found to be temporary (Whittingham et al., 2006).

Manipulation of chemical inputs

A reduction in pesticide use is beneficial for a number of wild bird populations. A wide range of farmland bird species showed rapid population increases as a result changing from normal crop regimes to mixed cropping and low pesticide regimes associated with commercial crop rotation (Henderson et al., 2009). Results very likely to be driven by increases in food abundance as carabids and weeds increased and results varied between granivores and insectivores (Henderson et al., 2009). Specific examples of bird populations responding to reduced pesticide use include Grey Partridges which increased in response to non-spraying of field edges and Skylarks which increased where there was unsprayed setaside (Newton, 2004a). Skylark nest density was seven times higher on organic farms than on conventional farms in the Netherlands, mainly due to differences in availability of nesting habitat (Kragten et al., 2008). Grey Partridges increased after herbicides and pesticides were excluded from the edges of cereal crops, leading to increases in insect abundance, plant density, plant species richness and Grey Partridge chick survival (Sotherton et al., 2014). Earthworm abundance was highest where moderate Nitrogenous fertiliser was used, which may benefit species such as Lapwings (Wakeham-Dawson and Smith, 2000).

Other habitat alterations

Other successful conservation management options include raising water levels, which has been found to reverse some wader population declines and can also benefit Yellow Wagtails (Newton, 2004). Mire restoration was found to be beneficial for Black Grouse (Malkova and Prochazka, 2003). However, there were conflicting results as O'Brien and Wilson (2011) found that AES management options that raised water levels appeared to decrease the benefits to waders of reduced grazing. There may be a trade-off between soil invertebrate accessibility (increased by softer soils that result from flooding) and invertebrate biomass (which declines as a result of flooding) (Wakeham-Dawson and Smith, 2000). Blocking moorland drainage ditches has been experimentally confirmed to increase densities of invertebrate prey such as Cranefly larvae (Carroll et al., 2011), and could potentially mitigate against the negative impacts of summer warming on soil invertebrate populations, thus protecting Golden Plover population (Pearce-Higgins et al., 2010).

Providing patches of bare ground or unsown areas can benefit some species: providing bare ground as part of English agri-environmental schemes has benefitted breeding lapwings (Chamberlain et al., 2009a) and Skylark populations increased due to the provision of unsown patches in cereal fields (Newton, 2004).

Hedgerows planting can provide nesting habitat and food resources for many bird species (Newton, 2004). However, linear features such as hedgerows may also increase predation and Grey Partridges had a negative association with hedgerows (Davey et al., 2010a). Nevertheless, hedgerows can benefit Partridges (Potts, 2012), though their benefits may be related to or contingent on other

types of management, such as maintenance of ground cover or effective levels of predator control. Linear wetland habitat structures, such as ditches and field edges, are commonly used to increase wader densities and have not been found to affect Lapwing nest predation (Eglington et al., 2008). Creating new native woodlands is likely to benefit some species including Black Grouse (Malkova and Prochazka, 2003). Woodland management options to increase populations of a range of woodland species, suggested in a review by Eglington and Noble (2010) include controlling grazing, creating coppice woods, increasing scrub, new woodland and thicket stages, restructuring closed canopy woodland with species such as birch, and reversing woodland drainage.

Collisions with deer fences cause some mortality in Capercaillie, Black Grouse and Red Grouse. The mortality risk can be reduced by removing or marking fences (Baines and Andrew, 2003; Summers et al., 2004a). Heather burning positively correlated with Red Grouse and Golden Plover density while had a negative impact on Meadow Pipit (Tharme et al., 2001).

Food provision

Supplementary feeding of predators is an option carried out to reduce predation of commercial gamebirds. Research indicates that supplementary feeding of predators is likely to increase predator populations under some circumstances. Supplementary feeding of Hen Harriers in spring increased Hen Harrier productivity (Redpath et al., 2001). Supplementary feeding of Buzzards before egg-laying increased the clutch size but did not affect the brood size while supplementary feeding after egg hatching neutralized the negative effect of poor habitat (Rooney et al., 2015).

Winter food for farmland birds is generally provided by growing winter crops or by providing seed directly. Siriwardena et al. (2007) found some but limited evidence for positive effects of winter supplementary seed feeding on farmland birds. In southern Scotland winter crops planted for gamebirds increased songbird populations (Sage et al., 2005). Higher populations of songbirds are associated with woodland and farmland where winter food is provided for lowland gamebirds (Tapper, 2005).

Supplementary feeding of songbirds is commonly carried out in gardens over winter, and has been shown to increase productivity in subsequent breeding seasons (Robb et al., 2008). Experimental provision of food has led to increases in breeding density of Great and Blue Tits in several studies (reviewed by Newton 2013). It is likely that the main reason for such increases was, in many cases, increased over-winter survival (particularly during years when alternative food was scarce), but immigration from surrounding areas may also have contributed.

Provisioning of gamebirds has been used as a management technique to increase numbers (or stem declines (reviewed by Newton, 2013). Management has involved direct provision of artificial feed (to bolster winter survival of Black Grouse in Finland), and manipulation of naturally occurring food sources through application of fertiliser (to increase growth of heather for Red Grouse) and reduced pesticide input (to increase insect availability in farmland for Grey Partridges). Such measures have met with variable success, depending principally on whether food was the main limiting factor constraining population growth rates.

COMBINED MANAGEMENT

Agri-environmental schemes

The effectiveness of agri-environmental schemes (AES) are difficult to assess because of generally inadequate monitoring (Whittingham, 2007). A meta-analysis by Whittingham (2007) found that of 19 bird studies AES had positive effects in four, negative effects in two and 11 showed results in both directions, making it clear that the effects vary between species, schemes and regions. AES may be more beneficial for biodiversity if a lower number of larger resource patches are provided, in contrast to current practices (Whittingham, 2007). In the Netherlands AES were not found to effectively increase the breeding densities of target bird species (Kleijn et al., 2001).

In general there was some evidence that higher level schemes and more targeted schemes had some positive impacts, particularly for seed-eating birds (Newton, 2004a). Changes in population density were more positive on farms with Higher Level Stewardship than farms outside AES in at least one of three regions in England for six of fifteen farmland species (Bright et al., 2015). These species were Grey Partridge, Lapwing, Reed Bunting, Tree Sparrow, House Sparrow and Yellowhammer. There is also evidence showing that Skylark breeding densities have responded positively to some AES. The effectiveness of three years of Entry Level Stewardship (ELS) management in England varied between farmland bird species but there was little evidence of overall benefit for most species and they were detrimental for some species including Northern Lapwing (Davey et al., 2010b). Current research indicates that the Higher Level Scheme (HLS) and Environmental Stewardship (ES) may be more effective in reducing bird declines than ELS (Eglington and Noble, 2010).

Corn Bunting and Common Starling populations showed some positive correlation with ELS management and half of the payments for ELS were for boundary management such as reducing the frequency of hedge cutting (Davey et al., 2010b). Corn Bunting populations in Scotland increased by 5.6% on farms with targeted Corn Bunting management, compared to no change on farms with general AES management and declines of 14.5% on farms with no AES management (Perkins et al., 2011). Targeted management included delayed mowing of grass grown for silage where Corn Buntings were nesting. Results suggest that approximately 72% of the Corn Bunting population in mainland Scotland would need to receive targeted AES management to halt Corn Bunting declines (Perkins et al., 2011). Corn Bunting and Skylarks were found to increase in Special Protected Areas (SPA) managed for the conservation of Little Bustard in France, with the provision of hay meadows and alfalfa, limited fertilization and optional delayed mowing (Brodier et al., 2014).

AES appear to have relatively successfully slowed wader declines in Scotland, particularly for Lapwings and Redshank, but they have not resulted in many populations increases (O'Brien and Wilson, 2011; Smart et al., 2013). In the Netherlands the four most common wader species were observed less frequently on fields with AES than without (Kleijn et al., 2001). AES options for waders includes reducing agricultural grazing and operations during the wader breeding season and creation or maintenance of wet field conditions increases (O'Brien and Wilson, 2011). The impact of AES appears to be largely due to reduced grazing (O'Brien and Wilson, 2011; Malpas et al., 2013b). Wilson et al. (2005) carried out a comparison of breeding populations of Oystercatcher, Lapwing, Snipe, Curlew and Redshank on sites designated as nature reserves, Sites of Special Scientific Interest (SSSI) and AES including Countryside Stewardship Schemes (CSS), Environmentally Sensitive Area (ESA), Low Tier options, ESA High Tier options and ESA Reversion options. No

combination of protection and management schemes affected Oystercatcher, Snipe or Curlew population trends while Redshank often benefitted from ESA options (Low Tier, High Tier and Reversion) and from SSSI designation (Wilson et al., 2005). Lapwing population trends were more positive areas with some combinations of site protection and ESA options while CSS did not appear to benefit the waders (Wilson et al., 2005). Meadow restoration in Sweden did not increase Lapwing populations because they still preferentially bred on tilled land where mortality due to agricultural operations was high (Berg et al., 2002). A study from the Netherlands found that Lapwings benefitted from "mosaic" management at a larger scale than single-field management previously carried out in AES (Wilson et al., 2005). Evidence of benefits for the other species (Black-tailed Godwit, Redshank and Oystercatcher) was less conclusive (Oosterveld et al., 2011). AES may be more effective if the efforts are targeted to existing wetland sites as there is high site fidelity in some wetland birds (Eglington and Noble, 2010).

Lowland game management

There are a range of studies in which multiple management options were carried out, making it difficult to identify whether a particular option or the combination of all options drove a population change. Multiple management options were commonly carried out to increase Grey Partridge and Pheasant populations. Nesting habitat provision, predator control and ensuring sufficient insect food for chicks or supplementary feeding increased Grey Partridge populations (Draycott, 2012; Ewald et al., 2012; Sotherton et al., 2014). Songbirds were benefitted by management for Pheasants including predator control supplementary winter and spring grain feeding, provision of perennial grasses in field boundaries and unharvested crops (Stoate, 2001).

Moorland game management

For a more detailed treatment of predator control, which is an integral component of moorland game management, please see the earlier section on Predator management and, in particular, the sub-section on Mixed species control. Grouse moor management is carried out over much of upland Britain and aims to increase populations of gamebirds, in particular Red Grouse for shooting. However, Red Grouse populations have declined in Scotland since the 1970s (Smith, 2009). Management generally includes predator control and habitat management including control of grazing densities and heather burning that maintains heather habitats. As these management activities are carried out together, the effects of each activity can be difficult to interpret. For example, some studies have used gamekeeper activity as a proxy for predator control, measured as presence/ absence at an estate level (Baines, 1996; Tharme et al., 2001), or as gamekeeper density at a landscape level (Douglas et al., 2014). Although one such study found no evidence of impacts on prey populations (Baines, 1996), others found that gamekeepers were associated with higher prey densities (Douglas et al., 2014; Tharme et al., 2001). However, this kind of observational study makes it difficult or impossible to discern the effects of predator control from other aspects of estate management such as burning and grazing of livestock and deer.

In southwest Scotland the apparent effects of 10 years of moorland management on bird populations was examined and was generally found to be negligible or even negative (Calladine et al., 2014b). The management included manipulations of grazing, burning and cutting, blocking drains

and controlling predators. Stonechats and Carrion Crows increased, despite active removal of Carrion Crows while Red Grouse, Skylarks and Meadow Pipits declined. Golden Plover, Curlew, Snipe and Wrens were not affected (Calladine et al., 2014b).

In another moorland management experiment in Southern Scotland at Langholm moor, after 7 years of habitat management and predator control, the area of heather had increased as had Hen Harrier and other raptor populations (Langholm Moor Demonstration Project, 2014). Passerine populations, upland wader and Red Grouse populations increased marginally, although Red Grouse density was not high enough for shooting to resume (Langholm Moor Demonstration Project, 2014; Yorke, 2015). Red Grouse mortality was largely due to unidentified raptor predation while the abundance of grouse predators was largely determined by the abundance of their main prey: voles, rabbits and carrion for foxes; Meadow Pipits and voles for Hen Harriers (Smith, 2000).

Another study examining the impact of grouse moor management in northern England and eastern Scotland found that Golden Plover densities increased on grouse moors, Skylarks, Whinchats, Carrion Crow and Hooded Crow declined and Lapwing, Red Grouse, Curlew and Meadow Pipits did not have significant population changes (Tharme et al., 2001). However, possible increases in Meadow Pipit, Curlew, Lapwing and Merlin due to grouse moor management were noted by Newton (1998) and Tapper (2005). Conversely, the vegetation changes associated with burning and grazing in can reduce the suitability of managed moorlands for some bird species (Bourne, 1988; Vanhinsbergh & Chamberlain, 2001). In Scotland and the wider UK, spatial variation in the abundance and breeding success of some raptor species has been shown to be strongly correlated with grouse moor management and recorded instances of illegal killing of these species. These species include Peregrines (Banks et al., 2010; Amar et al., 2012; North East Scotland Raptor Study Group, 2015) and Hen Harriers (Etheridge et al., 1997; Green and Etheridge, 1999; Fielding et al. 2011). While individual correlative studies cannot be taken as definitive evidence of the main driver of raptor populations, taken together these strongly suggest that moorland management is capable of limiting the numbers and productivity of some raptor species. Such effects would be likely to result in further consequences for prey populations of these species (e.g. Thirgood et al., 2000). See [Predator drivers of change section](#) for more details.

Grey Partridge Management

Grey Partridge populations have declined [see [trends section](#)]. There is a close link between Grey Partridge chick survival and population change (Potts and Aebischer, 1995; Aebischer and Ewald, 2004; Pepin et al., 2008) so management to increase chick survival is likely to be most effective at assisting their recovery. In 1995 Grey Partridge was designated as a priority species in the UK under the Biodiversity action plan and the Grey Partridge recovery programme was launched, led by the Game Conservancy Trust (Aebischer and Ewald, 2004). Under this, the Partridge Count Scheme has been used to assess the effectiveness of agri-environmental schemes to restore Grey Partridge populations. Grey Partridge were one of the farmland species benefitted by Higher Level Stewardship (Bright et al., 2015).

Improving habitat quality may be the most effective method to restore Grey Partridge populations to pre-crash levels, restoring insect-rich chick habitats, seed-rich winter habitats and suitable nesting cover (Kuijper et al., 2009). Predator control has also successfully increased Grey Partridge

productivity and breeding density (Pearson & Stoate, 1994; Tapper 1991; Tapper et al., 1996; Aebischer & Ewald, 2004)

Three groups of habitat management options have been identified as being most beneficial to Grey Partridges: beetle banks, conservation headland and wild bird cover (Ewald et al., 2010). [More details about beetle banks] Beetle banks provide mid-field nesting cover, whereas many options that provide nesting cover are located in field edges. Field edges are likely to have higher predation risk from mammalian predators (Ewald et al., 2010). Conservation headlands can almost double Grey Partridge brood size (Sotherton, 1991). The benefits of conservation headlands are probably due to increases in winter seed availability in the weedy understorey and increases in summer insect availability (Ewald et al., 2010). Wild bird cover, 6m uncropped, cultivated margins on arable land also provide additional food resources for Grey Partridge throughout the year. Options that increased scrub and areas of rough grazing were detrimental for Grey Partridge (Ewald et al., 2010).

Lapwing responses to land-use change and AES

Lapwing populations rapidly declined in the 1980s and were probably due to increasing agricultural intensity which increases mortality from farming operations, livestock trampling and predation (Hudson et al., 1994) and decreases breeding habitat (Milsom, 2005) and food availability (Taylor and Grant, 2004; Eglington et al., 2010) (see [Lapwing habitat and land-use section](#) for more detail).

AES appear to have relatively successfully slowed Lapwing declines but they have not resulted in populations increases (O'Brien and Wilson, 2011) except where combined with site protection such as on nature reserves or Sites of Special Scientific Interest (Wilson et al., 2005). However, AES is not always beneficial: Lapwing were one of the farmland species that benefitted from Higher Level Stewardship, which has options that specifically target Lapwings (Bright et al., 2015). Entry Level Stewardship, which has fewer species-specific options, was found to be detrimental for Lapwing populations (Davey et al., 2010b).

Restricting grazing and farming operation in the breeding season are management options that are commonly beneficial for lapwings (Hudson et al., 1994; O'Brien and Wilson, 2011). However, where protected meadows were provided Lapwing populations did not necessarily increase because they still preferentially bred on tilled land where mortality due to agricultural operations was high (Berg et al., 2002). Management at a larger scale than single-field management may reduce this problem (Wilson et al., 2005).

Providing bare ground as part of English agri-environmental schemes has benefitted breeding lapwings (Chamberlain et al., 2009a). Lapwing nest survival increased with spring and summer fallow ground (Sheldon et al., 2007) and abundance correlated with winter stubble (Gillings et al., 2005a) and winter cereals (Gillings et al., 2010).

6.2 Stakeholder definitions of ‘healthy’ populations

6.2.1 Stakeholder Knowledge – definitions of ‘healthy’ populations

6.2.1.1 Questionnaire results

To discuss feasible conservation-management options with stakeholders, it was first necessary to explore shared management goals. Central to this was a need to understand how stakeholders defined ‘healthy’ populations of wild bird prey and their main predators.

The definitions given for healthy populations varied between knowledge groups according to their land management objectives (Table 12). The most common aim among both stakeholder groups was to achieve an overall balance and/or sustainability of both predator and prey populations allowing for fluctuating populations of both but stability over the longer term. However, ideas of balance and sustainability varied between the groups, reflecting their management objectives. Both groups aimed to promote or maintain prey populations but Local Knowledge respondents more frequently thought this could be achieved by controlling predators while Scientific Knowledge respondents thought that current conservation strategies could be made more effective by limiting some human behaviours. Seminar participants acknowledged that different stakeholders have different objectives regarding desired numbers of predator and prey species and that it may be important to accept that concepts of healthy populations in localised areas may differ accordingly.

Table 12. Summary of respondents’ definitions of “healthy” populations of predators and prey species in upland and lowland systems in Scotland according to preference for local or scientific knowledge. Showing proportion of respondents within each knowledge group whose statements were coded under each definition. NB: some statements were coded under more than one definition. Source: questionnaire respondents, n=321.

Summary of definition	Local knowledge (211)	Scientific knowledge (110)
Overall balance/sustainability	82%	82%
Control predators/promote prey	46%	28%
Limit impact of some human behaviours on conservation/environment	0%	9%

For many of the Local Knowledge respondents, balance (33%) and sustainable predator-prey balance (26%) were highlighted in many of their definitions of healthy populations “A variety of predators and a healthy ground-nesting bird population.” (Appendix 12) One respondent defined healthy populations as “A balance between predator populations and prey populations so that both can achieve a state of equilibrium. Not that that means that populations cannot fluctuate. Healthy would mean populations which were large enough and robust enough to withstand density independent

events such as severe weather. Ideally, the populations would be as self-sustaining as possible.” The role of human intervention, for example through predator control and land management, according to many respondents with a preference for local knowledge was key in achieving such a balance, or *“re-balance... and motivate farmers and land owners to legally control predators and set aside land where waders can breed.”* For some, this means a period of reducing or controlling numbers of individuals of certain predator species to maintain or protect prey species *“a lack of management would leave areas with very small populations for long periods of time. This benefits no-one and is unhealthy.”*

Scientific Knowledge respondents defined healthy populations as self-sustaining (26%), implying *“a natural system of self-regulating populations”*, and *“long-term sustainability in populations of a diverse range of characteristic species in both upland and lowland habitats, i.e. maintaining populations as viable components of their breeding and wintering habitats.”*

Balance was also a recurring theme, which one respondent noted could result in a *“landscape that supports a proper balance of all species that might be expected to inhabit it.”* Stability was also a term associated with healthy population, resulting in *“a stable system which supports a sustainable population of both predator and prey, whereby an equal appreciation of both species importance is recognised.”*

For other respondents the emphasis was more on natural levels of numbers where populations did not negatively impact on other species, and where numbers are at the very least maintained (or recovered if considered too low). The role of human intervention to achieve such a balance or sustainability was perceived by some Scientific Knowledge respondents as essential, for example by managing the habitat, creating reserves, re-introducing certain species (e.g. lynx), controlling the release of non-native species, managing *“populations of predators in specific circumstances to aid the conservation of vulnerable prey species”* through *“predator control and habitat management [...that] can only be sustained by an economically viable accompanying land-use.”* Others from this group advocated a situation *“where nature is left to find its own natural balance without the need for human intervention”*, with populations *“kept in check by ecological mechanisms rather than human management”*, potentially resulting in *“a new balance and a new community structure.”*

In terms of the areas of convergence and divergence on the definition of healthy populations, there were large areas of agreement on the definition of healthy populations, with all respondents highlighting key terms such as balance, sustainability, and the desire to maintain or increase biodiversity. The greatest area of divergence was around how to achieve such a balance, with 14% of Local Knowledge respondents arguing for the need to manage predator populations, as opposed to 1% from the Scientific Knowledge respondents. Scientific Knowledge respondents thought that current conservation strategies could be made more effective by limiting some human behaviours (9%).

6.2.1.2 Seminar results

Participants from the seminars were asked on what basis we should determine/define healthy populations for predator and prey species.

Many participants mentioned the need for balance and a situation in which predators and prey are in equilibrium. Some groups mentioned the need to move to a more “natural system” where

predators influence their prey and vice versa. Many groups did not define healthy in terms of absolute number but noted there are “degrees of healthy”. Minimum requirements might be at the very least a presence of all species, if not sustainable or even thriving – although both latter terms caused discussions over their definitions. Natural fluctuations of predator and prey species, as well as context-dependence (e.g. time and scale) were also mentioned in the definition of ‘healthy’ populations. The subjective nature of setting a definition was also called into question, with participants asking who decides on what is right, according to whom, at what scale and why. Building on many of these above aspects, a definition of healthy populations was provided in one of the groups as the *“Presence of species (i.e. assemblage of birds, animals and plants) you would expect at a level that is sustained in terms of the management objectives of the land (compliant with public policy), acknowledging natural fluctuations.”*

The participants also discussed the elements needed to reach healthy populations. These discussions included the need for a diversity of habitats, positive land-use management, promoting opportunities for prey species to increase, understanding the interactions between different predators for example where predators can benefit breeding success of prey populations by controlling other predators. Participants noted the need for more information on specific species (e.g. curlews).

Finally, seminar participants acknowledged that different stakeholders may have different objectives regarding desired numbers of predator and prey species and that it may be important to accept that concepts of healthy populations in localised areas may differ accordingly. This led some participants to call for a large scale balanced approach caring for Scotland’s landscapes across a wide range of land-uses. The next steps would involve jointly deciding on what stakeholders want and their motivations, to follow on with joint action in terms of reaching these objectives.

6.3 Stakeholder understanding of effectiveness of management options

6.3.1 Questionnaire results

Respondents in the Local Knowledge group differed from those in the Scientific Knowledge group in their views on the effectiveness of different management techniques. 11% of the Local Knowledge group compared with 22% of the Scientific Knowledge group claimed not to have any understanding or experience of any of the conservation-management techniques *‘for managing predator-prey interactions in upland and lowland systems’* tested and were therefore excluded from further analysis. Considering only respondents who rated the effectiveness of ‘predator control’, 91% Local Knowledge respondents considered that direct predator control was ‘generally effective’, as opposed to 55% of Scientific Knowledge respondents ($X^2 = 40.71$, $df = 2$, $P < 0.001$). However, the responses of Local and Scientific Knowledge groups were more similar for ‘habitat management’ ($X^2 = 4.2$, $df = 2$, $P = 0.12$) and ‘other predator management’ techniques ($X^2 = 2.3$, $df = 2$, $p = 0.32$). Respondents in both groups had more confidence in the effectiveness of ‘habitat management’ than that of ‘other predator management’ techniques, very few rating the latter technique as ‘generally effective’. For both Knowledge groups, the proportion of respondents not rating each technique was

highest for 'other predator management' (39% for Local Knowledge respondents and 26% for Scientific Knowledge respondents) and lowest for 'predator control' (9% for Local Knowledge respondents, 16% for Scientific Knowledge respondents).

Differences in opinion regarding the most effective strategy for achieving healthy populations of predator and prey species mostly stemmed from conflicting attitudes regarding proximate threats to ground-nesting birds and associated differing management objectives. Those who saw predators as the most immediate threat prioritised localised predator control as an effective, fast-acting conservation-management strategy, declaring that no-one wanted to see predators eradicated completely: *"We don't want to eradicate anything, we just want to be allowed to manage things properly and show you that these vulnerable species will come back... I took on a hill... that was an amazing habitat... it should have had curlews, lapwings, everything on it. Within two years it was alive with Whinchats, ...Lapwings, Curlews. The only difference was proper predator control"* (LK#3).

Those who viewed human activities as the most important threats prioritised improving habitat quality across the landscape as their long-term goal *"...these wader species were here presumably since the last Ice Age in the presence of predators. What can we do even to a limited extent to recreate on the land the systems and the factors that allowed them to coexist? Now that will be a difficult uphill task but it's one we should start thinking from..."* (SK#2).

Predator control was described by both Local and Scientific Knowledge respondents as directly reducing predator numbers and benefitting other species in the long run (Table 13). Some respondents from both groups based their assessments on evidence from managed or 'keepered' areas. Respondents from both groups suggested that predator control was most effective when used with some form of habitat management technique. Local Knowledge respondents were also likely to base their assessment on personal experience and suggested predator control is the most effective or practical option available while Scientific Knowledge respondents were more likely to base their assessment on scientific evidence.

A variety of habitat management techniques was identified as effective by very small numbers of Local and Scientific Knowledge respondents each, most of which were directed at promoting prey populations (

Table 14).

Table 13. Questionnaire respondents' reasons most frequently given for choosing 'directly reducing predator numbers (control)' as the most effective technique overall, according to those who rated this technique as 'generally effective'. Shown in order of frequency of mentions according to respondents in the local knowledge group; many respondents gave more than one reason. Source: questionnaire respondents, n=188.

Reason	Type of knowledge preferred	
	Local knowledge (150)	Scientific knowledge (38)
Beneficial to other species	35%	24%
Efficacy based on local or personal experience	21%	5%
Efficacy based on evidence from 'keepered' or managed areas	18%	13%
Most effective or practical option available	14%	0%
Directly reduces predator numbers	14%	21%
No reason given	7%	1%
Trapping is effective for some species	5%	0%
When used in combination with habitat management	5%	0%
Efficacy based on evidence from scientific studies	4%	24%
Effective when used in combination with managing cover for prey	3%	3%
Effective when used in combination with habitat management and food	3%	8%
Aim is to reduce numbers of individuals not eradicate them	3%	0%
Combination of different techniques required for different species	2%	3%
Combination of techniques required	2%	8%

Table 14. Questionnaire respondents' reasons for choosing habitat management techniques as the most effective techniques overall, according to those who rated 'managing cover for prey', 'managing food abundance/quality for prey', 'managing habitat for predators' and/or managing prey availability for predators' as 'generally effective'. Shown in order of frequency of mentions overall; some respondents gave more than one reason. Source: questionnaire respondents, n=54.

Technique	Reason	Type of knowledge preferred	
		Local knowledge (29)	Scientific knowledge (25)
Habitat management in general (8)	Healthy populations of predators and prey can be sustained in long-term	1	2
	We need ecologically complex/naturalised/balanced landscapes	1	2
	Effectiveness will vary depending on place/habitat	0	2
	Need to allow predators to co-exist alongside prey	0	1
Cover for prey (7)	Prey species tend to be healthier and more abundant, providing sustainable food for predators	1	0
	Effective and ethical	0	1
	Provides refuges for prey/mitigates predator effect	1	2
	Leads to more available food for prey	0	1
	No specific reason given	0	1
Cover and food abundance and quality for prey (6)	No specific reason given	1	1
	Invertebrate food for chicks is critical	0	1
	If habitats are in good condition, predator effects are more sustainable	0	1
	Most effective technique - tried and tested	1	0
	Increased prey numbers from effective resource allocation	0	1
Food abundance and quality for prey (5)	Creates healthy populations of prey species	3	0
	Increases prey populations which are less likely to be affected by predators	1	0
	Healthy thriving prey = healthy predators	1	0
	No specific reason given	2	0
Habitat management and predator control (4)	Increases prey species	2	1
	Versatile land management	1	0
Cover for prey and predator control (3)	Healthier prey species numbers	1	0
	Key to biodiversity	1	0
	No specific reason given	1	0
Cover and food abundance and quality for prey and predator control (2)	More effective than using any single technique alone	0	2
Prey availability (1)	No specific reason given	1	0

6.3.2 Workshop results

Workshop participants discussed numerous techniques to varying degrees for the conservation-management of ground-nesting birds in general. General predator control was discussed in most depth and often in the context of positive or negative stakeholder relationships which were said to strongly influence predator management goals. Many local knowledge and some scientific knowledge participants rated predator control as effective due to the fact that an urgent problem requires a fast-acting solution and that reducing predator numbers is proven to benefit numerous species, not only those prioritised as important; this was mainly based on evidence from scientific studies, personal experience or evidence from “*keepered*” or managed areas. It was also described as the most effective or practical option available. However, to be effective the technique is generally ascribed to multiple species across multiple properties since unmanaged areas can be “*stewing pots*” for predators. Regulation and licencing of diverse conservation-management activities were also important to participants in all workshop groups, especially in regard to understanding drivers of illegal behaviour. Due to the highly political nature of predator management and related issues, including perceived levels of social acceptability of different conservation-management techniques, most groups also raised the need to better understand public perceptions about the causes for and potential solutions to address ground-nesting bird population decline.

PREDATOR CONTROL

There was joint concern between local and scientific knowledge workshop participants about the cumulative effect of an increase in the variety of predator species and in number of individual predators inevitably impacting on a range of prey species populations, including various protected species “*...if there's 20 eggs being laid the Pine Marten eats some, the Badger eats some, crows eat some, (Capercaillie are) never going to make it*” (LK#5). Some local knowledge participants were also worried about the long-term impacts of predators on prey survival and populations “*Oystercatchers might live... 20-25 years...every year it's lost its young and ... suddenly there are not just a few or too few Oystercatchers, there are none*” (LK#5).

Therefore, a major question facing those attempting to conserve ground-nesting birds is determining whether predator control is the most appropriate conservation-management strategy. It was suggested that “*Predation will have a greater impact where weather, food and habitat are less good for an individual species. A key question appears to be when conditions appear to be optimal, or as optimal as reasonable spending can achieve, does predator control have a critical or additional beneficial effect?*” (SK#3).

Some scientific knowledge participants expressed concern about the seeming lack of understanding among some land managers about predation “*...predation is a natural process... That will mean that we have lower numbers of some species. Predators will of course switch to other prey species after a while and there is a balance up of the other species*” (SK#2). They also described several instances where some predator species may be an asset to land managers (e.g. owls or raptors managing rat or vole populations, eagles attracting tourists) “*A small number of estates in the park have taken advantage of that particularly with respect to eagles because they are so iconic with wildlife photography*” (SK#2).

Among those land managers who took part in this study the consensus seemed to be that sustainable predator populations are a desirable part of the Scottish countryside *"We don't want to kill all the predators because we all value them; we see their part in the circle of life. But if we don't try and redress the balance very quickly, our natural heritage, Scottish natural heritage, ain't worth the title"* (LK#3).

Some scientific knowledge participants suggested that perceived drivers relating to ground-nesting species decline may be related to cultural values *"Certainly here it seems to be much more focused around these very intensive game management systems that we have. Most of our game management systems are predicated on producing very large numbers of huntable species. Whereas go to most other countries in Europe certainly and North America as well they don't have these high input high output hunting systems that we have. Therefore they seem less concerned about predation issues"* (SK#2). They considered the solutions relate more to modifying human behaviour, especially certain land-use practices, rather than modifying predator populations.

The other local and scientific knowledge participants suggested the solution was to modify predator behaviour, more specifically reducing population numbers of certain predator species. Participants in this latter group prioritised predator control as a more urgent need because of the fast rate of prey population decline but suggested that changing land-use practices and their associated impacts may be a viable longer term solution.

The main justification given by those local and scientific knowledge participants advocating predator control related to the amount of existing evidence demonstrating that directly reducing predator numbers is the most effective predator management strategy available *"...none of these other methods have been proven to be the most effective way. We know historically that removing predators is the best way and the most cost effective"* (SK#3). However, some scientific knowledge participants were less sure about determining the relative efficacy of predator control compared with other kinds of techniques *"...in terms of other predator, even legal predator control, if you [followed] the SRDP habitat management actions and you had an experiment to actually look at what the effect of predator control would be then we might be in a better position to work out what the relevant importance is"* (SK#2).

Numerous examples of scientific studies and on-ground experience were given by local and scientific knowledge participants demonstrating how successful predator control efforts have caused decreases in local predator populations and increases in prey populations, for example significant increases in Black Grouse populations were said to have been achieved on managed moorland where predator control has been carried out to a significant degree. These were also often said to have sometimes benefitted predator populations due to reduced competition for food or removal of less fit individuals *"This is another angle to predation management in that we want actually healthy populations of predators because that's a good thing for them and it's a good thing for their species, it's a good thing for the general ecosystem"* (LK#3).

The opposite was also said to be true: prey species populations were often seen to decline where predator control measures are reduced or stopped and this was thought to sometimes also detrimentally impact on predator population health over the longer term. Several local knowledge participants pointed to Ireland and Wales as examples of countries where limited predator control is

considered to have significantly impacted upon populations of ground-nesting bird species among others.

Scale of effort was described as critical *"...an important review paper last year (showed) international scale crow control doesn't really make any difference. But I know a number of people who for years have been controlling crows and magpies... with a massive impact locally... they would argue you wouldn't have the wide range of small birds... or hares and things like that"* (LK#2).

A major disadvantage of predator control mentioned by local and scientific knowledge participants is that this strategy requires coordinated, ongoing effort to be successful but is widely unsupported by public or political interests. Many thought this was due to a growing disconnection between urban populations and the natural environment with the result that a relatively small proportion of the general public is thought to understand either the *"true extent"* to which ground-nesting bird populations are declining or the causes of their decline. Due to the highly political nature of predator management, including perceived variation in the social acceptability of different conservation-management techniques, most groups also raised the need for public education to increase awareness of relevant issues and encourage greater support where appropriate.

Many workshop participants therefore highlighted the importance of working with neighbouring landowners, especially on land that may act as a predator *"sink"* (i.e. an area that attracts more predators than other areas due to greater availability of prey) to maintain predator populations at a level considered manageable according to particular interests. However, predator management across Scotland was described as ad hoc and efforts were said to be declining *"It costs money to control predators, and it is very difficult to find somebody who will do it if there isn't going to be a return"* (SK#1). This sometimes adds a significant financial and emotional burden to those involved in killing predators as part of their professional role *"...people don't choose to go and slaughter animals, if there was something cheaper and more effective they would probably be doing it"* (SK#3).

A major area of disagreement and possible conflict between some local and scientific knowledge participants related to differing economic and social priorities and some of this revolved around perceptions about natural versus artificial populations of focal species. As one scientific knowledge participant put it:

"If you look in the context of this study and the game bird people who have a slightly different view; their interpretation of a healthy population is having a shootable surplus of game birds at the end of the season to shoot which seems to be ever increasing. Whereas we're looking at natural populations, if you like... In England you have exceptional densities of some of these wading bird species for example which is quite likely if you remove all the natural predators of those species and have a decent habitat for them. If you go to Scandinavia - take Golden Plover as an example, you will never get those densities of Golden Plover. They're a thinly distributed species across most of their range. To us that would probably be acceptable" (SK#2).

Some scientific knowledge participants also suggested the nature of intensive game management in Scotland may be one of many factors exacerbating the perceived problem of predator impacts *"...high pheasant release is almost certain to increase the number of predators... What are the wider impacts of those predators on some of these ground-nesting birds?... that deserves to be scrutinised as well... maybe we're just looking at the symptoms here rather than the cause"* (SK#2).

Both local and scientific knowledge participants agreed that an abundance of prey species in areas relating to various land-use practices (e.g. game management, nature conservation or commercial forestry production) can attract or benefit predators. Moreover, it was also agreed that managing some predator species (e.g. those under General Licence) in a local area can attract other predator species (including protected species) due to greater prey availability and can sometimes create “*predator traps*” (e.g. prey species like Black Grouse can reach such low densities that legal management methods such as control of licenced species and habitat management cannot compensate for the impacts of predation by raptors). Therefore, it was suggested by some local and scientific knowledge groups that effective predator control involves controlling multiple species or “*predator suites*”. It was pointed out that although undertaking predator control as a “*bundle activity*” is reflected in scientific studies, which rarely focus on single species effects, the usefulness of such an approach is still under debate.

Most local knowledge participants agreed the most effective conservation-management strategy would involve a combination of habitat management and predator control, and that multi-species control efforts are often essential due to the cumulative impacts of several predator species interacting. Correct identification of predator species causing greatest local impact (e.g. using nest cameras or long-term observations) was identified as critical by both local and scientific knowledge participants since “*the most obvious predators may not be the ones you are thinking about*” (SK#2).

For a few local and scientific knowledge participants, zoning and quota systems could be useful if they allow appropriate management of problem predator species in certain areas to reduce numbers (but not eradicate them completely), and allow predator species to thrive in other areas where they are not considered a threat to prey species populations or livelihoods “*I would want to see what would happen by controlling what we can legally control first before starting to talk about wanting to control Buzzards and Harriers...*” (SK#1).

Protected predators

Opinions often clashed between local and scientific knowledge participants over recovering populations of protected predator species and whether some of the species considered more important in this context (e.g. Buzzard, Badger, Pine Marten, Raven) ought to be managed where they are proven to impact detrimentally on prey species.

Those advocating against management were concerned about raptor populations declining as has happened previously, for example due to the effects of persecution, using DDT and targeting raptors to protect racing pigeons during the war “*Very little changes in terms of some of the illegal practices that undermine real confidence in any process*” (SK#2). Those advocating for management suggested local population management would benefit both predator and prey species in the long run “*I don't see an issue with the Goshawk population, the Peregrine population, eagle population. There's not an issue with any population, other than the Ravens and Buzzards... if we were able to control that... you'd see a rise in (other populations), because there wouldn't be such a battle for food*” (LK#1).

The fragmented nature of predator management across Scotland was also seen as potentially facilitating management of some protected predator species at a local or regional level because they could still potentially thrive elsewhere.

Some scientific knowledge participants discussed the relationship between protected species and predator traps. As one scientific knowledge participant explained: *"I know a little bit about the grouse moors that have broken through the [predator] trap and are now producing surpluses in spades of grouse, and it's quite common to see raptors on those moors and they're perfectly tolerated because they can afford to lose a few grouse to Hen Harriers... If you've only got very few, every one you lose of every brood that's wiped out is another year wasted. And I think that's the argument of the responsible game managers, who are looking to get licenced control of the protected species"* (SK#1).

Licencing and regulation

The current licencing system was widely accepted as necessary by all participants. However, many local and scientific knowledge participants criticised the system due to difficulties regarding the management of some protected predator species and some constraints of the system were sometimes considered potential drivers of illegal behaviour. Some scientific knowledge participants called for better regulation of shooting counts while some local knowledge participants called for better auditing of environment-related grants and funding.

Licencing

A point of contention among some workshop participants was the seeming inconsistency between the way birds and mammals are valued as reflected in current environmental regulatory and licencing schemes. For example, all bird species are currently protected under the *EU Directive 2009/147/EC on the conservation of wild birds* (Birds Directive) (Joint Nature Conservation Committee 2014) and therefore general licences to control certain species (e.g. some corvids, gulls) in particular circumstances (e.g. agriculture, aviation) must be approved by Scottish Natural Heritage. On the other hand, non-bird wildlife species (e.g. mammals) considered to be endangered, vulnerable, rare and/or endemic are protected under the Habitats Directive (Directorate-General for Environment 2016). In the United Kingdom, some mammals (e.g. Red Fox, Stoat, Weasel but not Badger, Otter, Red Squirrel, Hedgehog, Pine Marten or Polecat) have no specific legal protection therefore it is legal to kill them as pest control as long as they are not on schedule 6 of the *Wildlife and Countryside Act 1981*. Some local knowledge participants were bewildered by the apparent higher status afforded avian predators over mammalian predators *"Why do you have that general licence for birds when you've got four-legged beasts that are doing exactly the same kind of damage on the ground?"* (LK#3). Some local knowledge participants felt that the legislation and licencing schemes no longer reflect local and national abundance of some protected predator species (e.g. Badgers, Buzzards) and suggested it was time to review both the Birds and Habitats Directives to ensure they are *"fit for purpose"* (LK#4).

Most local and scientific knowledge participants spoke of the difficulty for land managers in acquiring a licence, primarily to manage Ravens *"because very few people are even considering trying to get a license for a bird of prey because they perceive that there is no chance"* (SK#3). The licencing system was described as much stricter than that in England, and becoming stricter. Many local and scientific knowledge participants cited their experiences of bias in the licencing system regarding to whom and for what purpose a licence to manage Ravens might be granted *"It is becoming increasingly difficult to undertake predator control within the law. This, combined with*

reduced local labour on farms/estates, has meant that fewer people are trying to control what are an increasing number of predators with a decreasing array of techniques” (LK#2).

One scientific knowledge participant summed up the difficulties thus: *“...actually it’s quite difficult to get people to spend the time, money and effort doing it [applying for a Raven licence] and there is historical, cultural concern about the fact that at one point gamekeepers, shepherds, farmers and foresters were so effective at controlling these predators that they got them down to unbelievably low numbers, which is very strong residually within the conservation and legislative and regulatory bodies and the idea of trying to move forward, back to the position where this can be controlled at a manageable context is a huge hurdle for them” (SK#3).*

It was suggested in the same scientific workshop group that currently *“some of the most interesting questions that we might want or be able to generate answers for are subject to licencing constraint” (SK#3)* and that providing more legal methods of control may cut down on illegal behaviours regarding some protected species. Perhaps partly because the current legislative framework was said not to provide for control of Ravens to produce a *“shootable”* surplus of Grouse, these sentiments were echoed by many local knowledge participants; they expressed concern about their own or others’ inability to take legal action in the face of ongoing loss of livelihood or ground-nesting birds to predation by increasing populations of protected species *“...in a day when a flock of Ravens decides to fly with the wind north and lands on an area of ground... within 12 hours they could predate literally hundreds and hundreds of grouse eggs along with Golden Plover and all that... to individuals on the ground it’s a potential flashpoint... watching that happen” (LK#6).* However, it was suggested by these scientific knowledge participants that legalising currently illegal activities could potentially be regarded by some as *“giving in to blackmail”*.

Some local and scientific knowledge participants suggested the licencing system could be improved for example: if a robust, structured, well scrutinised, adaptive management type approach could be adopted, such as that currently existing in Scandinavia; if the process which currently allows airfield managers to control localised problem individuals could be adapted for use by other kinds of land managers where protected predators pose *“a specific risk in a specific area”*; or if it allowed for more responsive, local control of nomadic species (e.g. Raven) in justified circumstances.

Regulation

Participants from both local and scientific knowledge workshop groups talked about regulating different aspects of ground-nesting bird related conservation-management processes.

Of particular interest to one scientific knowledge group was regulation of wildlife hunting practices which they felt was much better managed and of lower intensity in some other European countries and in North America than in Scotland.

More specifically, these participants advocated for greater ease of access to game bag records currently held by individual estates and the Game and Wildlife Conservation Trust, and to licence records held by Scottish Natural Heritage, regarding numbers of quarry and pest species shot (e.g. Black Grouse, Grey Partridge, Carrion/Hooded Crow and Raven). Whereas state authorities in some countries (e.g. Germany) were said to set shooting quotas, in Scotland it was suggested that such quotas are self-regulated at the level of individual landowners resulting in a much less comprehensive overview of hunting practices and perhaps more opportunity for wildlife crime to

occur *"I'm afraid the criminal aspect of this does influence the debate to a large extent. Ultimately... a lot of it [comes down to] self-regulation by hunters and if they're not prepared to behave then the government needs to intervene and regulate"* (SK#2). Other European countries were described as policing wildlife crime more effectively by imposing serious fines or imprisonment on offenders *"In Spain we're hearing recently about these restoration orders that are now being applied. There are estates that have been convicted of killing Red Kites for example and then they get a fine and hunting rights removed until the species that were killed are restored back to healthy populations"* (SK#2).

Some local workshop groups felt that environmental heritage grants and other relevant funding or subsidy programs ought to be better audited and/or funds returned if funded activities have not been carried out satisfactorily *"It should be exactly the same for any ring-fenced project that the Scottish Government's involved in that has a natural heritage element to it. There needs to be value for money"* (LK#3).

Quotas

A small number of participants from one local knowledge and one scientific group specifically discussed quota schemes for managing predators although this kind of strategy was alluded to by some other local knowledge participants. There were some areas of agreement and disagreement.

Some of those who could see the benefit of a quota system referred to it in the context of the currently fragmented approach to predator management across the landscape *"if you're going to have islands of wildlife... a quota system is definitely the way forward to manage it"* (LK#5).

Participants in one scientific workshop proposed an experimental quota scheme to manage legally controlled predators in conjunction with appropriate SRDP habitat management actions with the aim of increasing understanding about the relative importance of predator control.

It was pointed out that varying degrees of tolerance for predators among different interest groups could make quota setting challenging. Those who did not support a quota system at all claimed that consensus would be difficult to find on such a hotly debated topic and advocated for changes to *"fundamental underlying land management practices"* instead.

Trapping and snaring

Participants in three local knowledge groups discussed their experiences of using traps (e.g. Larsen and cage traps) or snares to control crow, magpie and mustelid species. Participants said trapping can be a useful way to manage and monitor predator numbers. However, effective management of traps was considered onerous and regulation regarding the humane use of traps was thought to be reasonable but highly rigorous. Additionally, these participants all described how their traps are regularly vandalised by members of the public, despite being correctly tagged, and that political feeling is turning against trapping methods *"...the townsfolk who are by far the biggest political voice do not actually understand or know somebody who understands the ways of the countryside"* (LK#6). The fear of any irregularities being reported to the authorities discourages many land managers from using such methods *"I absolutely hate [using traps and snares] because I know if there's a single problem found with anything I'm doing, despite them being totally legal and my intention being totally legal and the operational trap being legal, the sky will fall on my head..."* (LK#6).

Predator exclusion

Fencing

Fencing off discrete areas (e.g. nature reserves) was viewed by many workshop participants as an effective means of protecting bird species of conservation concern from the impacts of terrestrial predator species (e.g. Badgers) but not from aerial predators (e.g. birds of prey or corvids). However, they generally agreed fencing is not a feasible large-scale predator management strategy due to practical and financial considerations. For example, concerns were raised about the potential for increased predator impacts on prey species excluded from fenced areas “...it doesn’t answer the question “What’s happening out in the broader countryside?”” (SK#1). Some local knowledge participants mentioned what they perceived as contentious scientific research suggesting numerous Capercaillie dying a direct result of fence collisions “This idea that a Caper just decided to fly into a fence in its territory... if they’re not being pursued by something on their tail they know that fence is there” (LK#5).

Nest cages

One scientific workshop group described how using nest cages can be an effective way to protect Lapwing from predation during the nesting and incubating phase.

Diversionsary feeding

One scientific workshop participant summarised the perceptions of many local and scientific knowledge participants who claimed to have direct experience of diversionsary feeding “...we are getting experience of [diversionsary feeding] but not to the degree that I’m confident to go out to the community and say “Yeah guys this works”... other people that have done it, haven’t written it up because it probably hasn’t worked or there’s been an enormous amount of variability in what they’ve done” (SK#3).

Perhaps the main concern among local knowledge participants was that helping birds of prey survive the winter months may reduce their natural mortality rate, increase breeding success and escalate potential for predation of ground-nesting birds in subsequent years “Ultimately they are birds of prey... You can feed them but they’ll still kill. You’ll get a young family of Buzzards practising on local populations of waders or pheasants... We can replace pheasants... but we cannot replace waders” (LK#3).

OTHER STRATEGIES TO REDUCE PREDATION

Catching and moving predators

Catching and moving was discussed by two local knowledge groups. This strategy was identified as a possible alternative to killing predators where the intention is to protect small isolated populations of threatened prey species (e.g. removing Pine Marten from Capercaillie habitat). However, it was also viewed as “dumping the problem elsewhere” and it was pointed out that territorial species (e.g. Sparrowhawk) are likely to return to an area if not translocated a sufficient distance away.

Scaring predators

Three local knowledge and one scientific knowledge workshop group discussed the inefficacy of various scaring techniques to deter corvid species such as crows and Ravens “Our problem at

Langholm comes from resident Ravens. You weren't allowed to shoot the ravens at the nest where you could shoot them humanely and before they laid eggs, you had to actually shoot them where they were doing the damage... and that's after you've tried to scare them off in every conceivable way. It is a problem" (SK#3). Scaring techniques were also described as *"sweeping the dust under the carpet"* since the individual *"doesn't go away and die, it goes away and eats something else"* (LK#5). Unintended consequences of using noise-deterrents included frightening individuals of other non-target species.

Zoning

Participants from three local knowledge and one scientific knowledge workshop group advocated evidence-based, landscape scale species management through zoning as opposed to species specific conservation *"...it is very harsh in some ways but we do subscribe to [the fact that] making sure your core population is secure and then trying to ensure that there is no further range loss is the right strategy rather than simply pouring money in to isolated populations in the hope that they will continue to survive"* (SK#3). This strategy was said to reflect *"the experience of keeping and farm management and also practical conservation studies that we've seen"* (SK#3).

HABITAT AND FOOD SUPPLY

Participants from all workshop groups agreed that appropriate habitat and habitat management practices are vital for ground-nesting bird species to prosper *"We've got a shared passion in wildlife and good habitat management"* (LK#3). Many local and scientific knowledge groups discussed the abundance of species typically found on kept land *"You can't have all the waders and stuff that we have without the habitat. So whatever our habitat is, if it's producing that it has to be the habitat"* (LK#5).

While both local and scientific knowledge participants discussed habitat quality and land-use change, some scientific knowledge workshop participants prioritised the impacts of habitat quality over those of predators on ground-nesting birds.

Scientific knowledge workshop participants who viewed habitat management strategies as more effective than predator control, mainly discussed conservation-management in the context of addressing socio-ecological issues and expressed views about holistic restoration of complex ecosystems and landscapes to their *"natural"* levels, although there was a lack of consensus about what natural levels might be. Curbing intensive, extractive industries (e.g. agriculture) and modifying land-use practices (e.g. over-grazing and excessive muirburn) to increase biodiversity were highlighted among many possible options. Where participants disagreed, it was to emphasise the immediate, mortal threat that predators pose and to recognise that predator management may still be necessary in some areas where habitat management strategies might be slow in taking effect *"Habitat quality and predation are not independent because... if you've got sub-optimum habitat then predation may become more of a problem"* (SK#1).

It was suggested that different land management strategies may lead to different compositions of species diversity, and that these compositions may be influenced by the degree to which localised predator control measures are implemented *"Although you might not get some of these species all in place where... there's not very much predator control, you get other species of a different composition"* (SK#2). It was therefore agreed by participants from both local and scientific

knowledge groups that in certain circumstances, a site-specific, tailored combination of habitat management and predator control could be an important management strategy for conserving the focal prey species.

Food abundance/quality for prey

A handful of local knowledge workshop participants explicitly discussed management of food abundance/quality for prey. Perhaps because it was perceived to be “*woven through the whole land management*” strategy it was not identified as a “*separate management operation*”. Some of these participants described a relationship between habitat quality, abundant food and healthier individuals or more diverse species “*Without suitable habitat there is also a lack of high protein invertebrate life for newly hatched chicks. So loss of habitat is a double edged sword... change of land-use, e.g. forestry, over-grazing, pesticide use on low ground wader habitat reduces food availability*” (LK#3). One participant pointed out that his ongoing farming efforts to grow wild bird seeds had been successful in increasing bird species diversity in his local area but have recently been “*totally truncated by a change in COP direction*” (LK#5).

Managing prey availability for predators

Participants from two local workshop groups talked specifically about managing prey availability for predators “*My view is that food is important. Rather than focusing on translocating raptors... if you provide enough relevant food in a specific area, you should have predators there*” (LK#3). Both groups suggested that appropriate management of mammalian predator populations (e.g. Red Fox, Stoat, Weasel) can increase some prey populations (e.g. hares) which may benefit birds of prey (e.g. eagles).

OTHER CONSERVATION MANAGEMENT STRATEGIES

Intra-guild predation

Many species were identified by workshop participants as intra-guild predators and the pros and cons of intra-guild predation as a conservation-management technique were discussed to some degree by both local and scientific knowledge groups.

Intra-guild predation between some species was seen to benefit populations of other species of conservation interest “*In the West Highlands and on Skye eagles are now having to predate foxes, which may have a beneficial impact on some ground-nesting birds*” (LK#3). However, this form of meso-predator population control may not be considered ideal to all stakeholders “*We’ve also got Goshawks that would be fantastic at controlling Sparrowhawks and all these corvids, and will eat and kill Buzzards but they’re just not welcome at all in game areas because they take Pheasants, Black Grouse, Red Squirrels*” (SK#1). Controlling legal predators such as Red Fox was sometimes said to have unintended consequences in terms of directly or indirectly increasing populations of other meso-predator species “*Take northern England... Stoats are a massive problem because there are no foxes... that has to be taken into account*” (SK#3).

The most in-depth discussion focussed on evidence of Red Fox depredation on various meso-predatory species such as Hen Harrier, Stoat, Weasel, Ferret and Short-eared Owls. Hen Harrier was mentioned most often as a victim of intra-guild predation, being identified as prey to Red Fox, Golden Eagle and Eagle Owl “*[On] the western isles... the Hen Harriers have got very poor breeding*

success because they're being clobbered by the Golden Eagles" (SK#1). Examples of other intra-guild interactions included: Badger predating on Hedgehog *"We're involved in a project trying to bring [Hedgehogs] back and we can't – Badgers are eating them"* (LK#6); Goshawk predating on Sparrowhawk, other hawk species, Buzzard and corvids; Sparrowhawk predating on Kestrel; and Buzzards possibly predating on Carrion Crow and Merlin.

Reintroduction of protected species

Five local knowledge groups talked about reintroduction of protected species. The majority of the discussion focused on reintroductions of Red Kite and White-tailed Sea-eagle populations, although Goshawk and Capercaillie were also mentioned.

Two major concerns emerged. The first focused on the perceived impacts on local prey populations resulting from a sudden, dramatic increase in local predator numbers – including those reintroduced and those attracted by associated supplementary feeding programs (e.g. gulls, corvids). Impacts were direct (e.g. mortality through predation) and indirect (e.g. mortality through predator disturbance) *"It's not like a pair or two pairs [of Red Kites]... a lot have got wing tags on so they've all been released... we see 50 of them going in to one roost. Five years ago, you'd see one or two"* (LK#1).

The second concern highlighted a lack of local consultation about the aims and objectives of raptor reintroduction programs and lack of available environmental impact assessments *"We were putting up a wind farm and had to do 10 years of study for the impact of that on birds... Yet the Red Kites get dropped off at the end of the road without a word, never knowing who does it"* (LK#5).

Another concern for some participants was the perceived prioritisation by conservation organisations of increasing raptor numbers while some prey species are declining *"It would be interesting to try and look at the total number of top level predators now compared with where it was 20 or 50 years ago, and then the same again on prey. I'm not sure there'll be very many more prey species here"* (LK#2).

Rewilding

Participants from two local knowledge and one scientific workshop group discussed rewilding of apex predator species such as Lynx. One potential benefit discussed was that such species *"...would help drive down the numbers of the meso-predators because of intra-guild competition and predation"* (LK#4). Positive examples were given of various apex predator species co-existing with humans in the vast natural landscapes across Fennoscandinavia, and it was suggested that some gamekeepers would see value in reintroducing Lynx into some areas to help with managing local Red Fox and Badger populations. However, the current social landscape in Scotland was viewed by some local knowledge participants as probably prohibitive to the success of Lynx rewilding programs due to potential negative impacts on farming and gamekeeping interests.

Agri-environmental schemes

Participants from one local knowledge and two scientific knowledge workshops talked about environmental stewardship schemes. *"High level"* schemes were said to deliver benefits for wildlife more effectively than *"low level"* schemes which were described as *"too lax"* in terms of certain land management prescriptions (e.g. slashing of hedges on an annual rather than tri-annual cycle). *"Some*

well thought out SRDP schemes have enhanced habitat quality and food availability. This may have been achieved through the creation of new habitats, enhancement of existing habitats and reduction in livestock numbers. Possibly reduction in herbicides/pesticides in some instances” (SK#3).

Introducing appropriate monitoring and auditing of subsidised land management activities were identified as two potential strategies which could improve these schemes *“Farmers are well used to measuring outputs... there’s all these management prescriptions... nobody’s actually checking them to see if they’re working” (SK#1).* Another suggestion to improve land stewardship included linking farm subsidy payments to higher level environmental schemes.

6.3.3 Seminar results

Predator control was considered by seminar participants to be a rapid, economically viable, effective option that could have an immediate and visible effect on what many considered the main driver of population change. For example, local knowledge holders may see an increase in prey populations as a result of predator control (*“If predator control works, you are more likely to continue using it”*). Teasing out the effects of other management techniques was perceived as more difficult and more long-term. Habitat management was also perceived as needing more widespread cooperation than predator control. There was a perception that local knowledge holders may have more and longer-term experience of predator control than other management techniques, building confidence in predator control. Seminar participants also suggested there was also a lack of knowledge of other forms of predator management techniques and their potential benefits.

6.4 Effectiveness of management options – comparison of natural science findings and stakeholder knowledge

6.4.1 Questionnaire results

A comparison of the effectiveness or otherwise of a range of conservation-management techniques as perceived by the Local Knowledge group, the Scientific Knowledge group and as reported in natural science reviewing, revealed some differences. Firstly, 11% of the Local Knowledge group compared with 22% of the Scientific Knowledge group claimed not to have any understanding or experience of any of the conservation-management techniques. Similarly, only 49 of all the scientific studies reviewed considered predator control or habitat management.

A greater proportion of studies have focused on the effectiveness of predator control and habitat management than on other forms of predator management (Figure 21a). Of the 49 scientific studies analysed, 41% suggested that predator control was effective at least some of the time (Figure 21a). This compared to 87% of the Local Knowledge group (Figure 21b) and 70% of the Scientific Knowledge group (Figure 21c) who considered predator control to be ‘generally effective’ or ‘effective/ineffective’. For habitat management, the comparative figures were 48% of studies, compared to 70% of the Scientific Knowledge group and 76% of the Local Knowledge group. Only two studies have analysed the effectiveness of other forms of predator management and there was less certainty amongst stakeholders as to their effectiveness.

In terms of proportions, more respondents than studies considered the efficacy of each kind of technique. Similar proportions of studies considered both predator control and habitat management to be effective or sometimes effective. Similar proportions of both the Local and Scientific Knowledge groups considered habitat management to be effective whereas the Local Knowledge group far more frequently supported predator control than the Scientific Knowledge group. Both groups acknowledged that the efficacy of habitat management was more likely to depend on the particular circumstances in which this technique is applied. In contrast, there was greater certainty within the Local Knowledge group that predator control is effective in most circumstances than within the Scientific Knowledge group, perhaps due to greater experience with this technique among Local Knowledge holders. There was clearly little research and far less understanding of the effectiveness or otherwise of other forms of predator management.

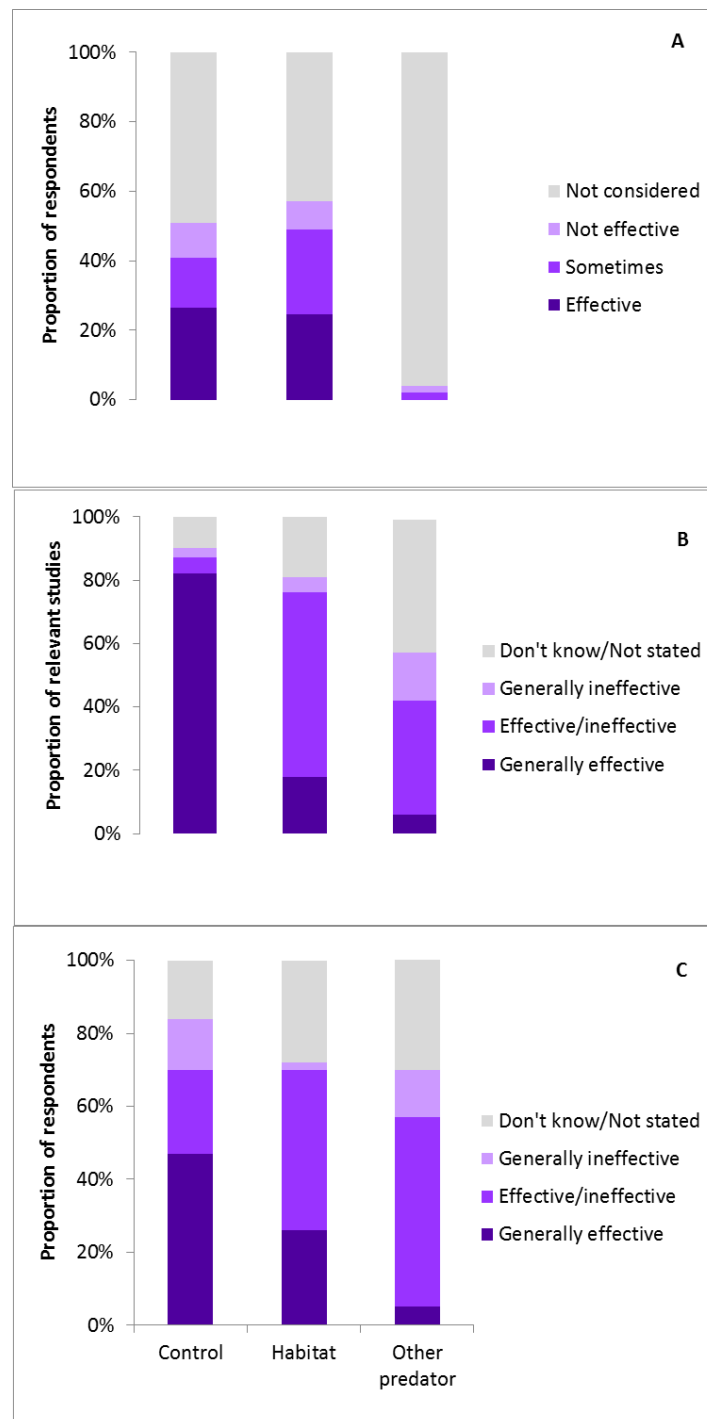


Figure 21. Comparison of findings from the natural science reviewing (A), Local Knowledge respondents (B) and Scientific Knowledge respondents (C) regarding effectiveness or otherwise of a range of conservation-management techniques. For the scientific reviewing, 49 separate scientific studies that considered the influence of management on gamebirds or waders were categorised for each management type as either 'effective', 'sometimes effective' or 'ineffective'. For the Local and Scientific Knowledge groups (n= 274), respondents rated conservation-management techniques for which they had understanding or direct experience as either 'generally effective', 'sometimes effective/sometimes ineffective', 'generally ineffective' or 'Don't know'.

6.4.2 Seminar results

Seminar participants considered that the finding that predator control was considered more effective by local knowledge holders than is suggested by the scientific literature could have been linked to differences in geographic scale. For example, comparisons of local areas where populations are sustained versus wider areas of population decline (sink effects). An important aspect was the need to improve the quality, practicality and ethical acceptability of scientific studies on predator control and to understand and consider public perception of predator control.

7. GAPS IN UNDERSTANDING & FUTURE PRIORITIES

7.1 Knowledge gaps

From the outset, this project did not seek to review the topics in order to identify research gaps and recommend future research for research's sake. Rather, the agreed objective was to focus on significant gaps in knowledge that currently prevent the community of interest from moving forward and limit management decisions.

Natural science knowledge gaps

Here we outline the range of ecological knowledge gaps that emerged during the course of the literature reviewing. We also discuss the importance of these gaps in limiting our understanding of, and our ability to address, the declines of the focal ground-nesting prey species considered by the project. It should be noted that none of these gaps preclude further actions being taken to foster collaboration and trust, and to identify and develop common goals among stakeholders in wild bird conservation. Indeed, many of the collaborative actions discussed in [section 7.2](#) could also contribute to addressing some of the knowledge gaps described below.

There is a paucity of available information on **alternative (non-lethal) predator management techniques** aimed at reducing the impact of predation on prey populations (e.g. diversionary feeding, taste aversion, etc.). If these techniques are effective, they could be very valuable tools in conservation of ground-nesting birds, especially in situations where lethal control of predators would run counter to law or other conservation priorities, or where lethal control of predators is not sufficiently effective. On the other hand, it may be that lack of field-based evidence, for at least some of these techniques, is largely due to their being impractical to use outside of the laboratory (Jonathan Reynolds, pers. comm.). For these techniques, making information relating to previous unsuccessful trials more readily available could enable more efficient allocation of resources, by preventing the need to replicate these studies, or else allowing future studies to focus on remaining areas of uncertainty.

There is a lack of robust information on the **economic, social and ecological impacts of protected predator species**, whose populations cannot be controlled legally. For a few of these, indications are that such impacts may be considerable, at least in some circumstances (Redpath, 1991; Langholm Moor Demonstration Project, 2014). In addition to the possibility that this knowledge gap is reducing the effectiveness of decisions made about the conservation of ground-nesting birds, it is also contributing to polarisation of views regarding raptors and predation impacts among some stakeholders. This is therefore an area where a combination of well-designed experiments and observational studies of predator movements and foraging behaviour and predation impacts could help to clarify the consequences of different management and regulatory options for prey populations, and remove some barriers to achieving consensus on some of these options.

The distinction made between experimental and observational studies above applies not just to studies of predation, but to many of the gaps of knowledge discussed in this section. Generally speaking, the

most reliable way to ascribe cause and effect in science is by generating experimental evidence, manipulating causes and observing the consequent effects. However, much of our current understanding of wild bird population drivers is not supported by experimental evidence. For some factors, such as climate change or illegal killing of protected predators, it is hard to imagine that true experimentation to determine their effect on populations will ever be possible. Happily, well-designed observational studies can also yield compelling evidence for the effects of predation and other processes on bird populations. Such observationally derived evidence should, typically, be derived in a consistent manner from multiple independent studies before it is regarded as reliable, and then interpreted with caution to avoid attributing cause incorrectly. When experiments can be carried out to test population-level effects of predation, every opportunity should be taken to ensure that the information these generate is useful to conservation managers, and complements existing literature on this subject.

Research on the **effects of human sources of food for generalist predators** on the abundance and impacts of these predators. These sources include gamebird releases, feed provided to livestock and game, and road kill. In particular, the ecological impacts of releasing large numbers of captive-reared gamebirds, most of which are non-native, are largely unknown. The potential for these and other impacts, both positive (Draycott et al. 2012) and negative (Larkman et al. 2015) to exert strong ecological effects is clear from the numbers of gamebirds, particularly Pheasants, released into the countryside each year (Park et al. 2008). Because predation-related impacts are particularly relevant to gamebird management, understanding whether and to what extent gamebird releases influence predation impacts could quickly be translated into changes in practice, with the hope of positive consequences for wild birds, and possibly also for relationships between stakeholders.

Further research on **interactions between habitat and predation** could benefit management aimed at improving the status of prey populations (Grant et al., 1999; Avery, 1989). These interactions include, but are not restricted to, the influence of landscape configuration on predator abundance and activity, effects of predator populations associated with one habitat on the prey populations supported by other, adjacent habitats, concentration of predator activity along boundaries and linear features, and effects of vegetation structure on concealment of birds and nests from predators and of predators from their prey. Habitat management is more widely accepted among the conservation community than more direct forms of predator management, and is already being carried out at local levels on individual reserves and estates and, through grant-aided agro-environment schemes, at landscape and country-wide levels. Understanding more about how it affects predation could reveal easy wins for conservation management, as well as situations where the effectiveness of habitat management aimed at enhancing bird populations was compromised by knock-on consequences for predation risk.

Another factor that hinders the ability of many studies to identify effects of predators is the lack of good data on many predator populations, resulting from a tendency of studies on predation effects to focus their efforts on collecting information on prey populations (Nicoll and Norris, 2010). This can make it difficult to determine the population impacts of predation at a large scale. In particular, there is a lack of available information on **drivers of corvid populations**, and even less information on **trends and drivers of most mammal predators**. Predation by these species, particularly of eggs and young birds,

can impact on other bird populations of conservation and economic importance. At a local level, this impact can often be mitigated by legal predator control programmes. However, there is currently no regulatory or other societal mechanism to ensure the effective management of corvids and mammal predators in the majority of areas, where dedicated predator control is not being practiced. It might be possible to reduce predatory impacts across large areas by managing landscapes to limit their suitability for corvids and generalist mammal predators. Like the aspects of habitat management discussed above, management of this sort has the additional benefit of being more acceptable to some stakeholders than management based on killing predators, and may therefore be more compatible with approaches seeking to increase collaboration and consensus between diverse stakeholder groups. This would require better knowledge of the population drivers of these species, in order to inform policy, regulation and best practice guidance relating to relevant aspects of landscape management.

A related issue is that there is a lack of published information on the size, movements, survival, behaviour and economic, social and ecological **impacts of non-breeding populations of several corvid and raptor species**. It is unlikely that traditional survey methods will ever yield a thorough understanding of these non-breeding populations, due to their mobility. However, it may be possible to combine information on survival and productivity of breeding adults with studies looking at the movements of non-breeding individuals (using colour marking or remote tracking) to build up a more comprehensive picture of non-breeding numbers and movements than we currently have. This could benefit several aspects of wild bird management by improving assessments of population drivers of these species (see above), their impacts on prey populations, the efficacy of predator control strategies that focus on breeding birds, and the resilience of predator populations in the face of such control.

There is currently little understanding about the extent to which **intra-guild effects** of top predators could influence numbers and activity of sub-dominant predators, and the degree to which such effects could benefit prey populations. Improved understanding of this process could, potentially, improve the effectiveness of management for conservation of prey populations. It could also help to narrow the ideological gap between some stakeholders primarily concerned with conservation of raptors and other mainly interested in managing for gamebirds, with positive consequences for conservation of both groups of birds.

A recent assessment of Eurasian Oystercatcher concluded that populations are stable or increasing over much of their large global range but declining in Europe, and that the relevant population drivers are not well understood (van de Pol et al., 2014). European declines in this and other species of waders are thought to be driven by poor productivity rather than by survival, but we have a better understanding of the former than the latter. In general, for migrants and partial migrants, we understand less of the importance of population **drivers that operate on over-winter survival** (and, for long-lived birds in particular, on pre-breeding season condition, which can affect probability and success of a breeding attempt) than those that operate directly on productivity and recruitment. It is unlikely that better understanding of determinants of over-winter survival would radically alter our ability to reverse declines of breeding wader populations. However, it might eventually enable us to take a more holistic approach to conservation of these species, so that if we do manage to address those factors currently

limiting productivity, we can also take measures to ensure that winter survival does not become a problem.

We found very little definitive information on the **effects of collisions with human structures**, such as road traffic, windows in buildings, wind turbines and ski infrastructure, on Scottish bird populations. It is unlikely that such collisions have played a large part in determining national population trends of most species, though localised impacts on populations of conservation importance are possible. In recent years, much assessment has been carried out to allow developers and regulators to assess such impacts, as they relate to individual developments. However, most of the information generated by these assessments is analysed piecemeal, greatly limiting its utility for conservation management. It would be better for all developers to follow standardised data collection protocols, to consolidate their information in industry-wide databases, and for these to be publically accessible. This would allow robust assessment of impacts on local, regional and national bird populations, and would eventually improve the efficiency with which developments could be regulated.

Few published studies clearly distinguish between the **effects of different predators**. This has led to wide ranging and sometimes conflicting or conjectural advice about the importance of certain predators (e.g. Park et al., 2005). This could be addressed by experimental work comparing the effects of single species control programmes with those control suites of predators. A better understanding of this issue could improve the efficacy of some predator control programmes. However, compensatory predation by uncontrolled species could, in many cases, make traditional mixed predator control programmes more effective than those targeting a subset of predator species.

Few Scotland-specific (or even relevant) studies have been carried out on the ecological (and, therefore, conservation) **impacts of disturbance**. Research indicates that disturbance by recreation, roads and ski infrastructure can influence some bird populations under some circumstances. However, whether these sources of disturbance can be important drivers of population change is unclear, and their effects at a large scale may be less important than those of other factors such as habitat and land-use change (Thiel et al., 2011). It is very unlikely that disturbance ranks among the main factors threatening the national population of any declining ground-nesting bird in Scotland, but it could be important at a local level, and could impact negatively on economic or conservation objectives of site managers.

There is little research on the **impacts of pollution** on bird populations (Eglington, 2009), and population level **effects of disease** are largely unknown, with a few exceptions (e.g. Browne *et al.* 2006). It is unlikely that these factors will be very important, at least in the short to medium term, for the majority of ground-nesting bird populations in Scotland.

Social science knowledge gaps

From the social science component of the work, a number of gaps in knowledge were identified by stakeholders, mainly through the workshop and seminar discussions. These were included in the synthesis of future collaborative actions explained in Section 7.2 below. The following gap in understanding was considered of particular importance and could be filled through social science:

- What are the drivers of illegal behaviour regarding management of protected predator species and how might these relate to predator licencing systems?

Priority gaps in understanding identified by the research team during the project that could be addressed by social science research included:

- A better understanding of what “healthy populations” of predator and prey species mean to different stakeholder groups, and why
- An understanding of differences in the willingness of influential stakeholders (e.g. conservation organisations, land managers, policy-makers, government officials, news media, general public) to accept information – what influences the willingness to accept information? Does this willingness vary between groups of stakeholders, and why?
- An understanding of the hindering/facilitating factors in the integration of local knowledge in decision-making.

7.2 Future collaborative actions

Many attendees at the Understanding Predation Project Review Seminars noted that the project had been a success in bringing the various interest groups together and providing them with opportunities to discuss the issues surrounding the declines of ground-nesting birds in Scotland and the role of predation in those declines. There was a shared aspiration amongst many attendees to find ways of maintaining this positive dialogue, and opportunities to work together through future collaborative actions. These future actions need not be research projects and some stakeholders expressed the need for urgent action to arrest population declines of the focal species rather than delaying to allow further research.

Collaborative actions can have several aims, which may include generating valuable information, and disseminating existing knowledge and understanding, as well as bringing together individuals and groups to work with one another. However, it is this latter element that is especially critical to continuing the positive interactions between the differing groups of stakeholders that have been an integral part of this project. In this section of the report, we endeavour to identify activities that can bring together people from different backgrounds, and with different knowledge, values and priorities, to engage in activities that allow them to share at least some common ground. These activities should enable participants to grow more familiar with one another, and to develop a mutual appreciation and respect for the perspectives of others. They will not make entrenched differences disappear overnight, but make it more likely that contentious issues will be given serious thought by all parties, and that compromises might be found that, ultimately, allow more effective conservation of ground-nesting wild birds in Scotland.

Methods

A list of ideas for future action was compiled based on responses to the online questionnaire, discussions during the Project Workshops, during the three Review Seminars and suggestions from the Project Steering Group, Review Panel and external referees from GWCT, JHI and RSPB during the reviewing of the draft report. The aim was to discuss the list of ideas further with stakeholders at a final additional Review Seminar but unfortunately this was not able to go ahead. To give interested stakeholders a chance to comment on the range of ideas and their merits further, the Research Group collated them into 29 possible future collaborative actions (Table 15) and asked stakeholders to assess these in a short survey.

The survey was prefaced by a short introduction, some brief instructions, and an overview of the 29 ideas that required rating. Participants were asked to rate each of 29 ideas against five different criteria:

- Opportunity for collaboration across a broad range of stakeholders
- Likely acceptability across a broad range of stakeholders
- Opportunity to build greater trust between sectors
- Opportunity to provide new insights and fill key gaps in current knowledge

- Level of priority / interest for the participant or their organisation

Participants were asked to rate each idea against all five criteria as 'High', 'Medium' or 'Low', responding 'Don't know' if they were not certain. They were given the opportunity to record up to three additional ideas for collaborative actions that they thought were important, but were not among the 29 ideas we had asked them to rate. Participants were also asked not to circulate the survey for others to fill in, in order to restrict participation to a pre-defined group of people who had all been involved in the project. These included the participants in all the three project seminars, the Steering Group, the review panel and expert reviewers of the draft report. This resulted in the survey being completed by a wide and representative cross-section of stakeholders (Table 16).

Table 15) which formed the basis of a short questionnaire survey which stakeholders were asked to participate in.

These future collaborative actions included:

- 8 actions aimed principally at fostering collaboration among the diverse groups of stakeholders with which the project has engaged;
- 16 actions aimed at addressing significant gaps in knowledge relevant to the ecology and management of wild birds; and
- 5 actions aimed at improving understanding of attitudes and values among the relevant community.

Many of these actions might contribute to multiple objectives if they were able to address one or more knowledge gaps or areas where understanding currently differs, at the same time as building trust through increased opportunities for dialogue and for working together, from design to delivery of these projects.

The survey was prefaced by a short introduction, some brief instructions, and an overview of the 29 ideas that required rating. Participants were asked to rate each of 29 ideas against five different criteria:

- Opportunity for collaboration across a broad range of stakeholders
- Likely acceptability across a broad range of stakeholders
- Opportunity to build greater trust between sectors
- Opportunity to provide new insights and fill key gaps in current knowledge
- Level of priority / interest for the participant or their organisation

Participants were asked to rate each idea against all five criteria as 'High', 'Medium' or 'Low', responding 'Don't know' if they were not certain. They were given the opportunity to record up to three additional ideas for collaborative actions that they thought were important, but were not among the 29 ideas we had asked them to rate. Participants were also asked not to circulate the survey for others to fill in, in order to restrict participation to a pre-defined group of people who had all been involved in the project. These included the participants in all the three project seminars, the Steering Group, the review panel and expert reviewers of the draft report. This resulted in the survey being completed by a wide and representative cross-section of stakeholders (Table 16).

Table 15. The 29 future collaborative actions as they were presented to stakeholders for assessment by survey in the Understanding Predation project. The ideas are grouped under three headings (Fostering Collaboration, Ecology & Management, and Attitudes & Values) according to their primary aims and foci, but most of these ideas could contribute to multiple collaborative objectives.

FOSTERING COLLABORATION

1. Establish an adaptive management forum consisting of nominated policy advisers, practitioners and researchers. Such a forum could be used to discuss and agree management strategies, and to ensure that practitioners are fully integrated in collaborative projects from inception to delivery and implementation of findings.

2. Hold regular workshops/meetings with interested stakeholders (e.g. policy advisers, practitioners and researchers). These would give interested parties from different sectors the opportunity to get together, share knowledge and seek consensus on relevant issues.

3. 'Walking in another person's shoes' – a professional-exchange program where representatives from different professions or key decision-making bodies can exchange roles for a time (e.g. day/week/month) to better understand the perspectives and decision-making of people in other sectors and organisations.

4. Develop a high-tech, web-based portal to act as an online facility to share observations, knowledge and collaborative opportunities within and between stakeholder groups and sectors.

5. Develop citizen science projects - programmes to train and engage volunteers from different stakeholder groups to take part in different kinds of organised wildlife surveys.

6. Promote and enhance BASC's Green Shoots mapping initiative, a programme to encourage members of the shooting community to provide records of wildlife and habitats, both on and off their shooting areas, on a regular basis.

7. Establish better links between monitoring and public awareness / education - find ways to better communicate wildlife survey findings to the public.

8. Establish large-scale demonstration sites to show the effectiveness of legal predator management. These could host trials to implement and assess different conservation-management strategies and promote those which are deemed most effective for conserving ground-nesting birds.

ECOLOGY & MANAGEMENT

9. Understanding causes of curlew decline (e.g. breeding success, habitat management, predator control, spatial variation).

10. Understanding recruitment and dispersal of black grouse (e.g. collecting information on breeding productivity, using remote tracking to get information on movements, foraging behaviour and survival, and combining this information with data on habitat, predators, land-use and management to inform understanding of population drivers).

11. Project to examine impact of legal predator removal on breeding success of ground-nesting birds - experimental approach to understand the effects of removing predators on the general licence, such as foxes, crows, stoats and weasels, using appropriate range of removal methods, control sites etc.

-
12. Project to examine impact of removal of protected species (e.g. buzzard, raven, goshawk, pine marten, badger) on breeding success of ground-nesting birds - experimental approach to understand the effects of removing predators on the general licence, using appropriate range of removal methods, control sites etc.
-
13. Gathering information on predation and predators (e.g. using camera traps or remote tracking to collect information on presence and movements of animals), to improve our understanding of predator numbers and activity and implications for prey populations.
-
14. Scale of predation impacts - legal predator removal experiments to examine how impacts of predators vary from the local scale to the landscape scale.
-
15. Experimental work on interactions between predator control and habitat management, such as investigating how the impact of predator control on nesting grouse varies in relation to habitat management.
-
16. Understanding the influence of land-use and landscape configuration on the abundance and activities of generalist predators. This would involve observational or experimental studies to investigate the potential for predation impacts on bird populations in different land-use types to be affected by the proximity, and size and shape of area, of other land-uses.
-
17. Effects of human-mediated prey/food availability on predator densities and activities at different landscape scales, including through deliberate provision of food to released or wild animal populations, introduction of non-native prey species, artificially high densities of native prey species, road kill, and refuse.
-
18. Comparing the ecological, social and economic consequences of different models of land-use (e.g. intensive management for hunting/shooting, low intensity management, no management and rewilded land).
-
19. Investigating the direct and indirect effects of human disturbance on ground-nesting birds - using a combination of observational and experimental approaches to look at and test effects of disturbance on the success of ongoing breeding attempts, as well as on the subsequent survival and productivity of disturbed adults, and young produced from these breeding attempts.
-
20. Understanding how the spatial pattern in predator removal across a landscape affects the abundance and behaviour of prey and predator species. This could involve a mixture of experimental and observational approaches, setting up predator control programmes (or finding existing ones) that operate at different spatial scales. The ability of these programmes to reduce predator numbers and conserve prey populations, at site, landscape and national levels, could then be compared.
-
21. Research into the benefits to society of economically non-productive land, including cultural value, ecosystem and public health, wildlife conservation, and recreation.
-
22. Intra-guild predation in raptors (e.g. Goshawks predating on corvids and Golden Eagles predating other birds of prey), and the consequences of this phenomenon for predator assemblages, behaviour of sub-dominant predators, and size and growth of prey populations.
-
23. Predator removal and compensation between predators – this would involve investigating the impact on numbers and behaviour of the remaining predators, and on prey populations, of predator control programmes targeting single predator species versus a range of species.
-
24. Comparing different predator control techniques - this would involve experimental
-

investigation of two or more different predator control techniques (e.g. shooting at different times of year, poisoning, snaring) to determine their relative effectiveness (at reducing predator densities and as a means of reducing the effect of predation on target prey populations).

ATTITUDES & VALUES

25. Explore how stakeholder attitudes and values regarding different predator species and related impacts of predation may influence conservation of ground-nesting birds - e.g. research to develop awareness / education programs based on a better understanding of stakeholder attitudes (e.g. general public, media, policy advisers, practitioners, researchers) towards different predator species and their impacts on ground-nesting birds.

26. Examine public attitudes towards and knowledge about impacts on ground-nesting bird populations, including those arising from predation, and the effects of different predator control techniques. This could involve research to assess levels of public tolerance for different predator management strategies via a survey of the general public.

27. Building a shared vision for the countryside - research to understand the perceptions held by different stakeholders about different predator and prey species (including what constitutes healthy populations of these species, and what are appropriate baseline population levels), and what sort of countryside stakeholders aspire to.

28. Understanding constraints to implementing licencing for specific protected predators, such as Buzzard - this would involve research and/or trials to determine what level of licencing, if any, could be acceptable to different stakeholders in the context of ground-nesting bird conservation and, if so, in what circumstances.

29. Enhancing predation management as a tool for ground-nesting bird conservation through the Scottish Rural Development Program (SRDP) - e.g. research and/or consultation with different stakeholders to understand how the SRDP can be used in a more targeted way to link predation management measures with habitat management measures.

Table 16. Affiliations of the 35 participants in the survey assessing and prioritising future collaborative actions suggested during the Understanding Predation project.

Organisations & Affiliations	Number
Association of Deer Management Groups	1
British Deer Society	1
Borders Forest Trust	1
British Moorlands	1
British Trust for Ornithology	1
Cairngorms National Park Association	2
Consultants and surveyors	2
Field Sports & Conservation	1
Game and Wildlife Conservancy Trust	1
Langholm Project	1
National Trust for Scotland	1
Review Panel	2
Scottish Association for Country Sports	1
Scottish Raptor Study Groups	2
Scottish Gamekeepers Association	3
Scottish Land and Estates	1
Scottish Natural Heritage	3
Songbird Survival	1
Sporting Estates	6
Wildlife Estates Scotland	1
Wildlife interests	1
University of Highlands and Islands	1

Survey assessments were numerically weighted to derive scores for each idea against each of the five criteria. Ratings of 'High' contributed a score of 2, 'Medium' a score of 1, and 'Low' a score of 0, with ratings of 'Don't know' not being included. The average score for each criterion provides an overall assessment across all survey participants, with scores close to 2 indicating consistently high ratings, and scores close to 0 indicating consistently low ratings. For each action, these scores are summed to give an overall score out of 10. These scores should not be interpreted as exact measures of project quality, but as indications of the relative value of and support for each project among the stakeholder community. The actions are ordered by rank according to this overall score in

Table 17. Additional suggestions provided by participants in the survey are listed in Table 18.

Results

Of the eight collaborative actions, the two scoring highest overall were action 1, involving the establishment of an adaptive management forum, and action 8, establishing one or more large demonstration projects (). Action 1 was rated very positively by stakeholders in terms of opportunities for collaboration, building trust, and individual prioritisation. Its lower rating for insight need not be a concern if the aim of such a project was primarily to foster good relations (though such a forum, if well managed, could be used to improve the evidence base on which decisions about management practice could be based). Action 8 was rated higher for insight, but lower for acceptability and priority. Several stakeholders' commented that previous, similarly large projects, such as Langholm, had proved very expensive, but had delivered little in terms of resolving disagreements and conflicts.

The highest scores for the 16 ecology and management actions went to actions 9, 10 and 13, placing these actions in the top ten in almost all categories (

Table 17). These are field-based projects, the first two of which are aimed at collecting more information on population drivers of Curlew and Black Grouse, respectively, and the third of which is aimed at collecting more information on predator activity. This kind of project could provide valuable opportunities for stakeholders to accumulate shared experiences and evidence relating to wild birds and their environment, contributing to the development of mutual trust and respect. The involvement of different stakeholders in the design, implementation and reporting of such studies does not preclude differences in interpretation, but it does make it more likely that agreement can be reached on what the data do and do not show. As well as providing stakeholders an opportunity to engage with one another and build up a shared body of experience and evidence, these projects also provide information that is valuable for conservation, of interest to a wide cross-section of stakeholders.

The highest overall score given to any of the 5 attitudes and values actions went to action 25, exploring and increasing societal awareness of stakeholder attitudes towards different predator species and the impact of predation (

Table 17). Ratings for this action were in the top 10 for all 5 criteria, indicating that many stakeholders believed that this action would not just be good for promoting collaboration, but had the potential to yield useful insights and to advance the interests of their sectors. During this project, many stakeholders expressed the belief that lack of understanding of predation among the public was one of the most significant barriers to legislative and regulatory change to enable better management of predators. The phrase “better management” would definitely mean different things to different stakeholders but, nevertheless, better and wider understanding of the values and attitudes of stakeholders would be a positive development.

Table 17. Average scores against each of five criteria (opportunity for collaboration across a broad range of stakeholders; likely acceptability across a broad range of stakeholders; opportunity to build greater trust between sectors; opportunity to provide new insights and fill key gaps in current knowledge; and level of priority / interest for the participant or their organisation) for 29 ideas relating to future collaborative actions, rated by 35 stakeholders who participated in an online survey. Participants gave each project a rating of ‘High’ (score = 2), ‘Medium’ (score = 1), ‘Low’ (score = 0) or ‘Don’t know’ (no score) against all five criteria. The top 10 scores under each criterion are shaded the same colour as the column header. For each project, average scores for each criterion, an overall score (from 0 to 10) combining scores for all five criteria, and a rank based on this score, are given in the table below. Projects are ordered by rank. [See the Methods section for further detail.](#)

Action	Collaboration	Acceptability	Trust	Insight	Priority	OVERALL	Rank
13	1.69	1.35	1.43	1.77	1.76	6.24	1
10	1.63	1.51	1.34	1.69	1.58	6.17	2
9	1.66	1.38	1.27	1.74	1.58	6.06	3
20	1.62	1.13	1.40	1.74	1.64	5.89	4
25	1.58	1.26	1.36	1.64	1.48	5.83	5
22	1.59	1.22	1.33	1.67	1.41	5.81	6
19	1.49	1.23	1.37	1.71	1.45	5.80	7
15	1.59	1.20	1.37	1.60	1.36	5.76	8
8	1.65	1.06	1.41	1.57	1.48	5.69	9
18	1.54	1.18	1.34	1.60	1.52	5.66	10
1	1.69	1.15	1.38	1.33	1.61	5.55	11
23	1.52	0.97	1.30	1.71	1.52	5.50	12
27	1.46	1.26	1.29	1.49	1.42	5.49	13
14	1.55	0.97	1.24	1.71	1.48	5.46	14
29	1.53	1.09	1.32	1.47	1.53	5.41	15
16	1.45	1.21	1.24	1.47	1.34	5.38	16
2	1.57	1.09	1.23	1.43	1.48	5.32	17
11	1.47	1.06	1.32	1.31	1.30	5.17	18
21	1.39	1.23	1.06	1.45	1.23	5.13	19
7	1.42	1.30	1.21	1.06	1.42	5.00	20
26	1.26	1.09	1.11	1.46	1.36	4.92	21
6	1.31	1.23	1.16	1.21	1.34	4.91	22
3	1.49	1.00	1.18	1.18	1.09	4.84	23
12	1.40	0.44	1.18	1.71	1.52	4.73	24
28	1.31	0.62	1.17	1.60	1.48	4.70	25
5	1.38	1.03	1.12	1.11	1.12	4.64	26
24	1.26	0.71	1.14	1.51	1.27	4.62	27
17	1.06	0.87	0.94	1.27	1.03	4.14	28
4	1.17	0.91	0.85	1.09	1.03	4.01	29

In order to be successful in engaging stakeholders, projects should ideally have a focus that is of immediate interest to them, and a remit that does not directly threaten their positions. For example, projects looking at the ecological effects of non-native game bird releases (e.g. action 17) or investigating the effect of removal of protected raptor species on breeding success of ground-nesting birds (e.g. action 12) could yield information that would support a case for societal change.

Such change might be welcomed by some stakeholders, and have positive consequences for society or wild bird conservation in the long run, but could also be perceived as threatening the interests or livelihoods of others. This could make it more difficult to successfully engender collaboration through such projects than through those aimed at generating information that all parties welcome and recognise the need for.

This is not to say that controversial projects are not important, nor that projects aimed primarily at filling knowledge gaps should necessarily be recognised as important by all stakeholders before they are carried out. Some other ideas for action that do not feature prominently in the ratings of the stakeholders could nevertheless make valuable contributions to stakeholder understanding of the issues dealt with by this project. These include actions 11, 16 and 17, which involve research on the ways that predator abundance and predation impacts are affected by legal predator control, human-managed landscapes, and human-mediated food sources. All of these projects could fill important gaps in currently available information on predation (in the case of projects looking at legal predator control, confirming and clarifying when and where effects that have been clearly demonstrated in a few studies apply in a wider variety of contexts), but were not recognised as being well-suited to encouraging collaborative action by the majority of stakeholders. Other projects, such as action 22 looking at the consequences of intra-guild effects for predator and prey assemblages, and action 23 on compensatory predation following removal of a subset of predators, were recognised by project stakeholders as having the potential to yield useful information, but were rated less positively in terms of respondent priorities (intra-guild predation) and potential for collaboration (compensatory predation).

Two other projects that were very positively rated, ranking in the top ten under four of the five criteria, were action 20 looking at the consequences of spatial pattern of predator removal, and action 25 exploring stakeholder values and attitudes towards different predator species. The first of these could have a strong, field-based component, though to generate the anticipated information it would have to be coordinated and synthesised at a large spatial scale. Nevertheless, it could also provide ample opportunity for stakeholders to work together on the ground, and (like actions 9, 10 and 13) could also help to build trust and relationships at higher levels of participating organisations through collaboration during design, coordination, analysis and reporting.

One final consideration concerns the investment of time that is required to develop true collaborations and foster continuing trust between different stakeholder interests. Many of the future actions identified as higher priority by stakeholders would constitute projects of fixed duration, and would not necessarily result in a step change in collaboration and trust that would be maintained in the longer-term. Possible future initiatives like actions 1 (adaptive management forum), 5 and 6 (with potential to develop wider stakeholder involvement in longer-term data collection and monitoring) would serve to increase collaboration and trust over longer timescales and could lead to greater overall ownership of the basic monitoring information on which a whole range of conservation-management decisions are currently based.

Table 18. Additional ideas for collaborative action put forward by participants in the survey

1. Sharing good practice for land management with socio-economic and biodiversity benefits
 2. Impacts of large scale game bird release on biodiversity
 3. Predator exclusion areas for conservation of ground-nesting birds
 4. Organisations gaining the necessary permissions to gain access to land to carry out what ever studies they wish to do. Covert studies/operations by bird organisations in the past have widened the gap between them and the sporting/rural community.
 5. More social science on understanding what motivates and historical context of, farmers, gamekeepers
 6. Game theory (walking in shoes) vital to see how other protagonists react to scenarios
 7. simple, frill-free, annual conference with no affiliation marked on attendees - in order to meet and spread common ground
 8. Broadening participation in established monitoring schemes and greater transparency of process/data
 9. Moorland Group/RSG joint events - field visits
 10. There is urgent need to compare impact of predation with impacts of habitat loss/impooverishment, pesticide use and reduced availability of invertebrate food (as reported in the journal Science in July 2014).
 11. Greater use of mathematical modelling to better understand the importance of predation relative to the other factors specified in Idea 1.
 12. Use some of the existing evidence that's out there and believe it. e.g. Grouse Moor Densities. A lot of the answers already exist from the Langholm project.
 13. Investigate the impact of high concentrations of red kites have on local biodiversity
 14. Survey training to ensure that species recording (presence, abundance, changes over time) is valuable to set the benchmark against predation can be measured
 15. Alongside, mapping & recording, development of simple recording app which would collate info and download to dbase / via mapping tool
 16. To amend through management bird species populations based on the red/amber/green grading to improve the opportunities for at risk species
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8. DISCUSSION

Those interested in Scottish wildlife, countryside and management gain their understanding and knowledge of predation from different sources. For some, it comes from science and findings of research projects, for others it comes from their experience and discussion with peers, and many people rely on a combination of both forms of knowledge. Scientific and local forms of knowledge have their strengths and their weaknesses. Science, when done well, can provide clear objective information to help guide management decisions, but it may ask questions that are inappropriate to managers and at the wrong spatial and temporal scale. Necessarily, science is often reductionist and may therefore lack the broader context. In contrast, local knowledge provides direct experience in the wider context, but without the rigour that experimental evidence brings. It can also be open to unintended bias. Yet there are powerful arguments for the need to develop an agreed evidence base and address the weaknesses on both sides through the co-production of knowledge.

This project was founded on the need “to establish and maintain balanced, healthy populations of all wild birds in Scotland and their predators”. Definitions included the notions of balance and sustainability, both opinions diverged over how to achieve healthy populations. The Local Knowledge group tended to focus on prey populations and predator control, whilst the Scientific Knowledge group focused more on promoting prey through limiting the impact of environmental or human factors.

There was common agreement amongst stakeholders that the six prey species that were the focus of this study had decreased and that three of the four predators had increased. The Local Knowledge group, however, considered that predators had increased more than the Scientific Knowledge group. The main argument given for this difference was related to differences in scale of understanding between the groups. The starkest difference between Local Knowledge understanding and the Atlas data was related to crows, with the former group considering that crows had increased, whereas the data from the Atlas was more equivocal.

Stakeholders were also in general agreement over the relative order of importance of the main factors thought to be responsible for population trends in these prey species. However, there were two principal differences. The local Knowledge group considered predation to be the most important factor, whilst the Scientific Knowledge group considered habitat to be most important. One reason for this is that predation is more obvious and immediate and the benefits of predator control are apparent in many cases. In contrast whilst the science may suggest that habitat management is important, its benefits may require management over a larger and longer time scale. These differences also emerged in relation to the relative effectiveness of predator control and habitat management.

So what next? On the topic of future research, the view shared by many at the project seminars, is that we need to move away from the current model of science feeding into policy and develop new collaborative approaches that develop robust science together with local knowledge holders from the outset, in agreeing the questions, designing the research, collecting the data and interpreting the results. Such knowledge co-production is a way of overcoming the perceived biases and building new knowledge that is accepted on both sides, especially in those areas where there is currently

disagreement. In addition to research, the divergent objectives around achieving “healthy populations” appeared at the heart of this project and will need to be discussed further to see if a common goal can be agreed and pursued. Maintaining the momentum on these shared challenges will be essential to keep all stakeholders engaged.

It will be valuable to explore more of the variation in the responses across different sectors. Currently we have analysed the information by Local and Scientific Knowledge groups, but within these groups there are a diversity of interests and affiliations. Exploring the variation across these groupings would help highlight the challenges and opportunities in developing future options.

9. LITERATURE CITED

Supplied as a separate PDF on the Moorland Forum website.

APPENDICES

Appendix 1: Questionnaire and workshop participants' organisational affiliation

List of organisations invited to participate in the Understanding Predation project.

Organisation Name	Moorland Forum Member
Angus and Dundee bird club	No
Argyll Bird Club	No
Arran Black Grouse Group	No
Association of Deer Management Groups	Yes
Association of Salmon Fishery Boards	No
Atholl Estates	No
Ballogie Estates	No
Balmoral Estate	No
British Association for Shooting and Conservation Scotland	Yes
Bat Conservation Trust	No
Wildlife Trust for Bedfordshire	No
Best Fox Call	No
Birders Against Wildlife Crime	No
Birse Community Trust	No
Borders College	No
Borders Forest Trust	No
Bowlts Chartered Surveyors	No
British Deer Society	Yes
British Ecological Society	No
British Falconers Club	No
British Ornithologists' Union	No
British Trust for Ornithology Scotland	Yes
Cairngorms National Park Authority	Yes
Centre for Ecology and Hydrology	No
Chartered Institute of Ecology and Environmental Management	No
CKD Galbraith	No
Clyde Muirshiel Regional Park Authority	No
Confor	Yes
Corrour Estate	No
Crofting Commission	Yes
Crown Office and Procurator Fiscal Service	No
Dalhousie Estates	Yes
Dee Ghillies Group	No
Dunecht Estates	No
Farming and Wildlife Advisory Group	No
Forest Enterprise Scotland	No
Forestry Commission Scotland	Yes

Galloway & Southern Ayrshire Biosphere	No
Game & Wildlife Conservation Trust	Yes
Game Conservancy Scottish Research Trustees	Yes
North Highland College Gamekeeping Department	No
Glen Tanar Estate	No
Highland Foundation for Wildlife	No
HM Revenue and Customs	No
Islesman Ltd	No
James Hutton Institute	Yes
JM Osborne	No
John Muir Trust	No
Land Agents	No
Langholm Moor Demonstration Project	No
League Against Cruel Sports	No
Local Fisheries Boards	No
Loch Lomond & Trossachs National Park Authority	Yes
Lomond Hills Regional Park Authority	No
Lowland Deer Network Scotland	No
Ministry of Defence	No
MOD Police	No
Moorland Trust/Moorland Association	No
Moray Bird Club	No
Mountain Training Association	No
National Museums Scotland	No
National Sheep Association	No
National Trust for Scotland	Yes
National Farmers Union Scotland	Yes
North East Mountain Trust	No
North Harris Trust	No
OneKind	No
Partnership for Action Against Wildlife Crime (PAW Scotland)	No
Pentland Hills Regional Park Authority	No
Police Scotland	No
Ramblers Association	No
Raptor Persecution Scotland	No
Raptor Politics	No
Rob Yorke	No
Royal Institution of Chartered Surveyors in Scotland	Yes
Royal Pigeon Racing Association	No
Royal Society of Edinburgh	No
RSPB Scotland	Yes
Rural Directorate	Yes
Strutt & Parker	No
Savills	No

Science and Advice for Scottish Agriculture	No
Scottish Association for Country Sports	Yes
Scottish Badgers	No
Scottish Country Sports Tourism Group	No
Scottish Countryside Alliance	Yes
Scottish Countryside Rangers Association	No
Scottish Crofting Federation	No
Scottish Environment LINK	No
Scottish Environment Protection Agency	Yes
Scottish Gamekeepers Association	Yes
Scottish Government	
Scottish Homing Union	No
Scottish Hydro	No
Scottish Land & Estates	Yes
Scottish Moorland Management Groups	No
Scottish Natural Heritage	Yes
Scottish Ornithologists Club	No
Scottish Power	No
Scottish Raptor Study Groups	Yes
Scottish Renewables	Yes
Scottish Rural Parliament	No
Scottish Society for the Prevention of Cruelty to Animals	No
Scottish Water	Yes
Scottish Waterways	No
Scottish Wildlife Trust	Yes
Sky High Falconry	No
Songbird Survival	Yes
Southern Uplands Partnership	No
SRUC	Yes
The Heather Trust	Yes
The Mammal Society	No
The Mountaineering Council of Scotland	No
Thurso College	No
TRACE Wildlife Forensics Network	No
Trees for Life	No
UK National Wildlife Crime Unit	No
United Utilities	No
Universities Federation For Animal Welfare	No
University of Highlands and Islands	No
Visit Scotland	No
Wild Media Foundation	No
Wild Scotland	No
Wildlife Estates Scotland	No

Appendix 2: Online questionnaire

Please see Understanding Predation_Questionnaire PDF document on the Moorland Forum website.

Appendix 3: Main topics of the online questionnaire

vii) Organisational affiliation and socio-demographic information:

Respondents were asked to name any organisations with which they are mainly associated (e.g. employee/member/volunteer) regarding predator-prey issues in Scotland. They were also asked to provide details about their gender and age;

viii) Interest and experience of predation of ground-nesting wild birds in the uplands and lowlands of Scotland:

Respondents were asked to describe in a couple of sentences why they are interested in predation of ground-nesting wild birds in upland and lowland systems in Scotland;

ix) Preferred forms of knowledge:

Respondents were asked to think about which forms of information are relevant to them when learning about predation of ground-nesting wild birds in general and to rate the importance of the following on a scale of 1 (very unimportant) to 5 (very important): academic/scientific peer-reviewed journals; information prepared for licence applications; knowledge passed on through peers; own scientific study; personal field observations or field management experience; photographic evidence; popular press; published or unpublished non-peer-reviewed literature. They could also nominate up to two additional appropriate forms of information. Respondents were then asked to consider all these forms of information and to identify a single form which was most important to them overall;

x) Perceptions of population abundance changes in predator and prey species:

Respondents were asked whether their experience was at a local, regional or national level. If they selected 'local' or 'regional' they were prompted to identify the appropriate county and presented with a map of Scotland to identify up to three local areas where they have most relevant experience, using alpha-numeric grid references. For each of these areas respondents indicated how they think abundance has changed over the last 25 years for each of the focal prey and predator species. Answers were also given a numeric code: large increase (+2); small increase (+1); no change (0); small decrease (-1); large decrease (-2); don't know);

xi) Drivers of change in prey and predators:

Respondents were presented with 10 common environmental and human factors: climate change/weather; deer numbers; disease; food availability; habitat quality; herbicides/pesticides; land-use change; livestock numbers; predators; and recreational disturbance. Two further optional responses were also provided: 'no environmental/human impact' and 'don't know'. Respondents could also nominate one additional factor deemed important. They were asked which, if any, of these factors they considered to have had a medium to high negative impact on the six species of ground-nesting wild birds. We ranked the order of importance for each of these factors according to the proportion of respondents within the local and scientific knowledge groups who nominated each factor. Questionnaire respondents were asked which, if any, of the four predator species has had a medium to high negative impact on the six prey species over the last 25 years;

xii) Conservation and management of predator-prey interactions:

Respondents were first asked to define 'healthy' in the context of the Understanding Predation project being 'founded on the goal of achieving healthy populations of predator and prey species in upland and lowland systems in Scotland'. Statements were then coded and summarised into categories. Next, respondents indicated which conservation/management-techniques they have an understanding of or experience with: 1. directly reducing predator numbers; 2. managing food abundance/quality/cover for prey; 3. managing habitat for predators; 4. managing prey availability for predators; 5. diversionary feeding for predators; 6. managing cover for prey; 7. catching and moving predators; and 8. zoning for predators. They could also nominate up to two more appropriate conservation-management techniques. These categories were subsequently placed in three groups of techniques – Direct Predator Control (1), Habitat Management (2-4), Other Predator Management (5-9). Respondents who stated they have an understanding of or experience with a technique were asked to rate its overall effectiveness for achieving healthy populations of predator and prey species as 'generally effective', 'sometimes ineffective/sometimes effective', 'generally ineffective' or 'don't know'.

Appendix 4: Understanding Predation workshop timetable and participants

Workshop date and venue	Participating organisation(s)	Number of participants	Knowledge classification
June 5th, Edinburgh	Game and Wildlife Conservation Trust	7	Scientific
10 th June, Dunkeld	British Association for Shooting and Conservation Scotland	6	Local
25 th June, Stirling	British Trust for Ornithology	6	Scientific
29 th June, Perth	Scottish Gamekeepers Association British Deer Society	10	Local
30 th June, Perth	Scottish Land and Estates The Heather Trust	6	Local
15 th July, Edinburgh	Scottish Countryside Association SongBird Survival	6	Local
21 st June, Dunkeld	Scottish Association for Country Sports	6	Local
22 nd June, Forfar	Angus Glens Moorland Group	5	Local
27 th June, Perth	Cairngorms National Park Authority James Hutton Institute RSPB Scotland Scottish Raptor Study Group	10	Scientific

Appendix 5: Understanding Predation workshop guide

Understanding Predation Workshop Guide

The Understanding Predation project is founded on the basis that stakeholders want to achieve healthy populations of predator and prey species in upland and lowland systems in Scotland. In this context, the purpose of the workshops is to help us identify and better understand areas of common ground and any differences of opinion between stakeholders. Today's workshop will take around two hours and will be run in three main parts. We'll explore:

1. the extent to which you base your understanding of predation on science and/or local knowledge, and how and why you decide which form of knowledge to prioritise;
2. your knowledge and understanding of changes in wild bird populations in upland and lowland systems in Scotland and the reasons for these changes; and
3. conservation and management goals for predator and prey species (in the context of maintaining healthy populations of both) and your knowledge and understanding of different techniques for achieving such goals.

Thank you all for completing the online questionnaire. We have done some preliminary analyses so we can discuss the most interesting findings. That inevitably means going through some questions that you've already answered in the questionnaire but we'll be looking at the group's overall results and will discuss these together in more depth. Throughout we will seek clarification, consistency and explicitness so that claims can be treated appropriately according to the level of supporting evidence and their overall relevance.

In terms of what we'll do with the information you provide: firstly, I'll send you a summary of what we've discussed today for your records. Then the results of all the workshops will be compiled and included in the project report. I have a draft report structure here, and it's on the Understanding Predation blog, if you'd like to look through it. The report will include findings from the natural science review, the online questionnaire and the workshops. The draft report will be presented to 3 seminars at the end of October/November where participants can provide their feedback. The final report is expected to be launched in February by the Minister for Environment, Climate Change and Land Reform.

May I have your consent to record this workshop, so we have an accurate record of what is discussed? This recording will be kept confidential to the Research Group and no statements will be directly attributed to any individual in our project outputs. Participants are free to use the information received, but neither the identity nor the affiliation of the speakers, nor that of any other participant, may be revealed by any party.

Workshop schedule

A. Introduction

Discuss rules of engagement.

Participants asked to introduce themselves and describe their interest in predation of ground-nesting wild birds in Scotland.

B. Current perceptions of predation of wild birds in upland and lowland systems in Scotland

Knowledge and information (20 minutes)

How is knowledge about predation currently gained?

Which forms of knowledge are considered most important, and why?

In what circumstances is local knowledge prioritised over scientific knowledge, and vice versa?

In what circumstances could knowledge change opinions/behaviour

What form might that knowledge take?

Who might influence opinions?

C. Changes in species abundance (20 minutes)

How do assessments of prey and predator species abundance change compare with Bird Atlas data?

Black Grouse; Curlew; Golden Plover; Grey Partridge; Lapwing; Oystercatcher;

Buzzard; Crow (Carrion/Hooded); Raven; Red Fox, Other species

Why do differences in opinions exist, if any?

Which other key predator species are significant, if any, and why?

What is the evidence for this?

D. Environmental and human impacts on ground-nesting wild bird prey species (20 minutes)

Which factors have most significant impact on individual prey species and what is the evidence for this?

Climate change/weather... etc.

Black Grouse; Curlew; Golden Plover; Grey Partridge; Lapwing; Oystercatcher

E. Impacts of predators on ground-nesting wild bird prey species (20 minutes)

If predators are not considered important, why is that? What is the evidence?

If there's a divergence in views about the impacts of predators, why is that, who thinks that?

If predators are considered important, which predators have most significant impact on individual focal prey species and what is the evidence for this?

Buzzard, Crow...etc.

Black Grouse; Curlew; Golden Plover; Grey Partridge; Lapwing; Oystercatcher

F. Conservation and management of predator-prey interactions

Conservation and management goals (10 minutes)

We'll be talking about different management strategies in a moment but first of all we'll explore conservation-management goals. As discussed earlier, this project is founded on the basis that stakeholders want to achieve healthy populations of predator and prey species in upland and lowland systems in Scotland.

What are the conservation-management goals you would like to see implemented in this context?

On what timescale?

On what spatial scale?

Efficacy of conservation-management techniques for predator-prey interactions (20 minutes)

Which two techniques are considered to be most effective, and why?

How have they helped achieve the goals identified above?

What is preventing goals being reached using these techniques?

Which additional techniques, if any, could be used to achieve these goals?

Which two techniques are considered least effective, and why?

Is there any context in which these techniques might be considered useful?

Appendix 6: Review seminar guides

Review Seminar Guide - Perth

Group discussion 1 – Use of knowledge (30 mins)

- What opportunities are there for us to produce knowledge together (local and scientific)?
- How can we best use local knowledge to design and frame scientific studies?

Group discussion 2 – Population trends of predators and focal prey species (30 mins)

- Can we agree which, if any, of the suggested reasons given in the briefing document may explain the difference in understanding of recent population changes for crows?
- Can you think of other possible reasons to explain the observed differences? (5 minutes)
- Are there any other findings from this part of the work that you consider we should explore in more detail?

Group discussion 3 – Impacts of predation and other drivers (30 mins)

- Can we suggest why local knowledge consistently ranks predation as the most important driver of population change in the six prey species, in contrast to the scientific literature?
- Can we suggest why local knowledge suggests recreational disturbance as a more important driver of population change in the six prey species, in contrast to the scientific literature?
- Are there any other similarities or differences that you consider are of particular interest or warrant further exploration?

Group discussion 4 – Conservation-management options (15 mins)

- Can we suggest why local knowledge respondents consider predator control more effective than is suggested by the scientific literature, and more effective than the other management techniques?
- Are there any other contrasts that you consider are of particular interest or warrant further exploration?

Plenary Session - Building a Common Future

- Future collaboration on research and other activities.

Review Seminar Guide - Inverness

Group discussion 1 – Use of knowledge (30 mins)

- What opportunities are there for us to produce knowledge together (local and scientific)?
- How can we best use local knowledge to design and frame scientific studies?

Group discussion 2 – Population trends of predators and focal prey species (30 mins)

- Can we agree which, if any, of the suggested reasons given in the briefing document may explain the difference in understanding of recent population changes for crows?
- Can you think of other possible reasons to explain the observed differences? (5 minutes)
- On what basis should we determine/define healthy populations for these species?
- Are there any other findings from this part of the work that you consider we should explore in more detail?

Group discussion 3 – Impacts & Conservation-management options (45 mins)

- Can we suggest why local knowledge consistently ranks predation as the most important driver of population change in the six prey species, in contrast to the scientific literature?
- Can we suggest why local knowledge suggests recreational disturbance as a more important driver of population change in the six prey species, in contrast to the scientific literature?
- Can we suggest why local knowledge respondents consider predator control more effective than is suggested by the scientific literature, and more effective than the other management techniques?
- Are there any interactions between drivers we should also be considering that are particularly relevant to regulation and management of wild bird populations?
- Are there any other contrasts from these results that you consider are of particular interest or warrant further exploration?

Group discussion 4 – Research questions (15 mins)

- What collaborative research or other activities should we seek to take forward together?

Plenary Session - Building a Common Future

- Future collaboration on research and other activities.

Review Seminar Guide - Edinburgh

Group discussion 1 – Use of knowledge (30 mins)

- Do we need both local and scientific knowledge?
- Do you think we have succeeded in bringing together local and scientific knowledge?
- Can you see opportunities to combine the two in future projects?

Group discussion 2 – Population trends of predators and focal prey species (30 mins)

- Can we agree which, if any, of the suggested reasons given in the briefing document may explain the difference in understanding of recent population changes for crows?
- Can you think of other possible reasons to explain the observed differences? (5 minutes)
- On what basis should we determine/define healthy populations for these species?
- Are there any other findings from this part of the work that you consider we should explore in more detail?

Group discussion 3 – Impacts & Conservation-management options (45 mins)

- Can we suggest why local knowledge consistently ranks predation as the most important driver of population change in the six prey species, in contrast to the scientific literature?
- Can we suggest why local knowledge suggests recreational disturbance as a more important driver of population change in the six prey species, in contrast to the scientific literature?
- Can we suggest why local knowledge respondents consider predator control more effective than is suggested by the scientific literature, and more effective than the other management techniques?
- What combinations of drivers are relevant to conservation-management of wild bird populations?

Group discussion 4 – Research questions (15 mins)

- What collaborative research or other activities should we seek to take forward together?

Plenary Session - Building a Common Future

- Future collaboration on research and other activities.

Appendix 7: 'Other' most important forms of information

When asked to identify the most important form of information when learning about predation of ground-nesting wild birds in general, 11% of questionnaire respondents chose 'information prepared for licence applications', 'other', 'own scientific study', 'photographic evidence', 'popular press' and 'published or unpublished non-peer-reviewed literature'.

Ten respondents chose photographic evidence, explaining that this is an effective way for land managers to pass on their local knowledge and the best methods of providing irrefutable evidence of predation, among other things.

A further ten respondents chose popular press as the most important form of information because it is an important, open and up to date format that can broadly disseminate knowledge and 'the truth' about the care and management of the countryside and its inhabitants *"It is open to everyone and not just a select few."*

Nine respondents said that published or unpublished non-peer-reviewed literature was most important, with one summarising the arguments thus: *"It distils down most of the other sources of information into a form which has a reasonably high degree of integrity and digestibility."* The sources of information referred to included personal field observations and peer-reviewed articles among others.

Six respondents chose 'own scientific study' as most important mainly because it is a practical way of compiling knowledge and applying strategies that are relevant to the local context.

'Other' forms of information were chosen by six respondents, for example: *"knowledge obtained by being on the lands everyday"*, *"the bigger picture from following several sources because no one source of info can ever provide all authority over time"*, *"national surveys"* and *"telling the truth regardless of public misconceptions."*

Finally, four respondents identified 'information prepared for licence applications' as most important. Some respondents explained that the general licence is legally binding in the context of their work and that preparing information for an application *"...should ascertain that there is indeed a need for a licence."*

Appendix 8: Local and Scientific Knowledge group respondents' organisational associations

Questionnaire respondents' associations with organisations (e.g. employee/member/volunteer) regarding predator-prey issues in Scotland (Q33) according to their preference for local or scientific knowledge when learning about predation of ground-nesting wild birds in general (Q25). Shown in order of frequency of mentions according to respondents in the local knowledge group; many respondents associated with more than one organisation and may be included multiple times; blank cells indicate no respondents associated with an organisation, n=321.

Organisational affiliation	Type of knowledge preferred	
	Local knowledge (211)	Scientific knowledge (110)
Scottish Gamekeepers' Association/gamekeeping	94 (45%)	10 (9%)
Game and Wildlife Conservation Trust	36 (17%)	17 (15%)
British Association for Shooting and Conservation	26 (12%)	11 (10%)
General public/no affiliation given	20 (9%)	15 (14%)
British Trust for Ornithology	17 (8%)	19 (17%)
Scottish Land and Estates/estate manager	17 (8%)	3 (3%)
Scottish Association for Country Sports/country sports	14 (7%)	1 (1%)
National Farmers' Union (Scotland)/farmer	12 (6%)	4 (4%)
Association of Deer Management Groups/British Deer Society/Lowland Deer Network Scotland	8 (4%)	9 (8%)
RSPB	7 (3%)	14 (13%)
Land agent/manager	5 (2%)	4 (4%)
Scottish Natural	5 (2%)	5 (5%)
Scottish Countryside Alliance	4 (2%)	3 (3%)
Non-government organisation (unspecified)	3 (1%)	1 (1%)
Scottish Ornithologists Club	3 (1%)	6 (5%)
Scottish Wildlife Trust	3 (1%)	5 (5%)
The Heather Trust	3 (1%)	1 (1%)
Forestry Commission Scotland/forestry	3 (1%)	2 (2%)
Cairngorms National Park Authority	2 (1%)	2 (2%)
Crofter	2 (1%)	
National Trust for Scotland	2 (1%)	3 (3%)
Police	2 (1%)	
Raptor Persecution Scotland	2 (1%)	1 (1%)
SongBird Survival	2 (1%)	1 (1%)
Scottish Raptor Study Groups	2 (1%)	11 (10%)
Wildlife Estates Scotland	2 (1%)	
Academic (unspecified)	1 (0%)	1 (1%)
British Falconers Club	1 (0%)	
British Forest Trust	1 (0%)	
Callander Black Grouse Project	1 (0%)	
Conservation (unspecified)	1 (0%)	
John Muir Trust	1 (0%)	1 (1%)

National Action Plan for Black Grouse	1 (0%)	
North Harris Trust	1 (0%)	
Operation Country Watch	1 (0%)	
Perth Society for Natural Science	1 (0%)	
River Dee Trust	1 (0%)	
Regional Park Authority	1 (0%)	
Scottish Crofters' Federation	1 (0%)	
Scottish Rural Property and Business Association	1 (0%)	
Scottish Society for the Prevention of Cruelty to Animals	1 (0%)	
Tweed Foundation	1 (0%)	

Appendix 9: Questionnaire respondents' socio-demographic information

Age

- i) 18 to 24 years: 5% of respondents;
- ii) 25 to 34 years: 9%;
- iii) 35 to 44 years: 12%;
- iv) 45 to 54 years: 27%
- v) 55 to 64 years: 26%;
- vi) 65 years or over: 20%; and
- vii) Prefer not to say 1%.

Length of interest in the predation of ground-nesting wild birds in the uplands and lowlands of Scotland

- viii) Up to five years: 7% of respondents;
- ix) Six to 10 years: 11%;
- x) 11 to 15 years: 10%;
- xi) 16 to 20 years: 11%' and
- xii) over 20 years: 61%.

Current or previous association (e.g. employee, volunteer or member) with different kinds of relevant organisations

- xiii) Conservation group or society: 74% of respondents;
- xiv) Hunting, shooting or fishing group or association: 69%;
- xv) Academic institution: 39%;
- xvi) National/regional bird group: 38%;
- xvii) Government agency: 21%;
- xviii) Scientific society: 21%;
- xix) National park authority: 11%;
- xx) Animal welfare or animal rights group: 6%;
- xxi) Not currently/never been a member of any of these kinds of organisations: 5%

Appendix 10: Organisational affiliation of questionnaire respondents

Between them, the 400 questionnaire respondents affiliated with approximately 70 different organisations or professions, with many holding several affiliations (total of 617 affiliations).

Questionnaire respondents' affiliation (e.g. employee, volunteer or member) with various kinds of organisations. Source questionnaire respondents, n=400.

Type of affiliation recorded	Number of respondents stating affiliation
Scottish Gamekeepers Association/gamekeepers/National Gamekeepers Organisation	125
Game and Wildlife Conservation Trust	66
British Trust for Ornithology	47
British Association for Shooting and Conservation	43
General public	37
RSPB	28
Association of Deer Management Groups/British Deer Society/LDNS	20
Scottish Association for Country Sports/country sports	19
Land managers/Scottish Rural Property & Business Association/MCIEEM	17
No affiliation or profession given	16
Scottish Raptor Study Group/Raptor Study Group	14
Scottish Land & Estates	14
SAIFCA/Farming	14
Scottish Natural Heritage	13
Scottish Ornithologists Club	13
Academics (e.g ecologists)	13
Estate managers/owners	10
Scottish Countryside Alliance	10
Scottish Wildlife Trust	9
Cairngorms NPA/NPA/RPA	8
Scottish Homing Union/pigeon fancying or racing	5
The Heather Trust	5
National Trust Scotland	5
NFUS	5
SongBird Survival	5
Forestry	6
Police	3
Scottish Crofting Federation/crofter	3
Conservation and wildlife groups (unspecified)	2
John Muir Trust	2
Wildfowl and Wetland Trust	2
Wildlife Estates Scotland	2
Government	2

Raptor Persecution Scotland	2
SRUC (inc SAC-Consulting)	2
Anglers Cooperative Association	1
Angling Trust	1
ANHS	1
Borders Forest Trust	1
British Falconers Club	1
Callander Black Grouse Project	1
Firearms UK	1
Hillwalker	1
JNCC Breeding Bird Survey	1
Lauderdale Hunt Supporters Club	1
Moorland Forum	1
National Action Plan for Black Grouse	1
Natural England	1
North Harris Trust	1
Operation Country Watch	1
PSNS (Perthshire Society of Natural Science?)	1
Royal Scottish Zoological Society	1
Salmon and Trout Association	1
Scottish Hawking Club	1
Scottish Moorland Group	1
Scottish Research Trust	1
SSPCA	1
Wild Trout Trust	1
Woodland Trust	1
James Hutton Institute	1
British Ecological Society	1
Society for Conservation Biology	1
Argyll Bird Club	1
River Dee Trust	1
Tweed Foundation	1
TOTAL	617

Appendix 11: Breeding distribution change at NHZ scale

Breeding distribution change (change in number of 10-km squares) between 1988-91 and 2008-11 for major avian predators of wild birds and six focal prey species in Scotland. Species for which regional change measures are less appropriate have been excluded from this appendix e.g. gulls). (Source: BTO/BWI/SOC Bird Atlas data for 1988-91 and 2008-11)

NHZ	RED KITE Name	Distribution 1970 - 2010			
		No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	3	562	31	1644
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	0	0	NA
3	Coll, Tiree & the Western Isles	0	0	0	NA
4	North West Seaboard	0	0	0	NA
5	The Peatlands of Caithness & Sutherland	0	0	0	NA
6	Western Seaboard	0	1	0	Inf
7	Northern Highlands	0	13	0	Inf
8	Western Highlands	0	0	0	NA
9	North East Coastal Plain	0	7	0	Inf
10	Central Highlands	0	4	0	Inf
11	Cairngorm Massif	0	4	0	Inf
12	North East Glens	0	10	0	Inf
13	East Lochaber	0	2	0	Inf
14	Argyll West and Islands	0	2	0	Inf
15	Loch Lomond, Trossachs & Breadalbane	0	13	0	Inf
16	Eastern Lowlands	0	16	0	Inf
17	West Central Belt	0	8	0	Inf
18	Wigtown Machairs & Outer Solway Coast	0	0	0	NA
19	Western Southern Uplands & Inner Solway	0	19	0	Inf
20	Border Hills	0	1	0	Inf
21	Moray Firth	0	11	0	Inf
	WHOLE OF SCOTLAND	0	111	0	INF

	WHITE-TAILED EAGLE	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	0	0	0	NA
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	0	0	NA
3	Coll, Tiree & the Western Isles	0	21	0	Inf
4	North West Seaboard	0	10	0	Inf
5	The Peatlands of Caithness & Sutherland	0	0	0	NA
6	Western Seaboard	0	41	0	Inf
7	Northern Highlands	0	1	0	Inf
8	Western Highlands	0	10	0	Inf
9	North East Coastal Plain	0	0	0	NA
10	Central Highlands	0	0	0	NA
11	Cairngorm Massif	0	0	0	NA
12	North East Glens	0	0	0	NA
13	East Lochaber	0	2	0	Inf
14	Argyll West and Islands	0	7	0	Inf
15	Loch Lomond, Trossachs & Breadalbane	0	0	0	NA
16	Eastern Lowlands	0	0	0	NA
17	West Central Belt	0	0	0	NA
18	Wigtown Machairs & Outer Solway Coast	0	0	0	NA
19	Western Southern Uplands & Inner Solway	0	0	0	NA
20	Border Hills	0	0	0	NA
21	Moray Firth	0	0	0	NA
	WHOLE OF SCOTLAND	0	92	0	INF

	HEN HARRIER	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	29	85	20	114
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	2	5	20	14
3	Coll, Tiree & the Western Isles	3	12	10	69
4	North West Seaboard	7	4	0	-43
5	The Peatlands of Caithness & Sutherland	9	17	24	24
6	Western Seaboard	3	27	10	185
7	Northern Highlands	8	8	6	0
8	Western Highlands	3	5	0	67
9	North East Coastal Plain	2	0	0	-100
10	Central Highlands	4	8	6	40
11	Cairngorm Massif	4	13	15	47
12	North East Glens	5	7	11	13
13	East Lochaber	4	6	2	33
14	Argyll West and Islands	11	23	44	22
15	Loch Lomond, Trossachs & Breadalbane	5	5	18	0
16	Eastern Lowlands	8	10	4	17
17	West Central Belt	6	1	12	-28
18	Wigtown Machairs & Outer Solway Coast	2	0	1	-67
19	Western Southern Uplands & Inner Solway	23	12	8	-35
20	Border Hills	10	10	5	0
21	Moray Firth	5	4	3	-13
	WHOLE OF SCOTLAND	124	177	199	16

	GOSHAWK	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	2	329	10	2725
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	0	0	NA
3	Coll, Tiree & the Western Isles	0	0	0	NA
4	North West Seaboard	0	0	0	NA
5	The Peatlands of Caithness & Sutherland	0	3	0	Inf
6	Western Seaboard	0	0	0	NA
7	Northern Highlands	1	4	0	300
8	Western Highlands	0	0	0	NA
9	North East Coastal Plain	0	6	1	600
10	Central Highlands	2	3	0	50
11	Cairngorm Massif	2	6	2	100
12	North East Glens	1	27	0	2600
13	East Lochaber	0	0	0	NA
14	Argyll West and Islands	1	2	0	100
15	Loch Lomond, Trossachs & Breadalbane	0	3	0	Inf
16	Eastern Lowlands	1	30	0	2900
17	West Central Belt	1	4	0	300
18	Wigtown Machairs & Outer Solway Coast	0	0	0	NA
19	Western Southern Uplands & Inner Solway	4	21	5	189
20	Border Hills	0	22	2	1100
21	Moray Firth	0	7	0	Inf
	WHOLE OF SCOTLAND	13	138	10	543

	SPARROWHAWK	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	34	456	1196	34
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	15	6	250
3	Coll, Tiree & the Western Isles	0	12	0	Inf
4	North West Seaboard	12	11	8	-5
5	The Peatlands of Caithness & Sutherland	7	17	21	36
6	Western Seaboard	8	22	14	64
7	Northern Highlands	12	9	24	-8
8	Western Highlands	5	6	6	9
9	North East Coastal Plain	1	12	27	39
10	Central Highlands	4	7	15	16
11	Cairngorm Massif	7	2	19	-19
12	North East Glens	4	3	26	-3
13	East Lochaber	7	4	11	-17
14	Argyll West and Islands	9	19	44	19
15	Loch Lomond, Trossachs & Breadalbane	7	9	18	8
16	Eastern Lowlands	0	23	78	29
17	West Central Belt	2	2	51	0
18	Wigtown Machairs & Outer Solway Coast	3	3	8	0
19	Western Southern Uplands & Inner Solway	2	8	63	9
20	Border Hills	2	3	36	3
21	Moray Firth	2	3	24	4
	WHOLE OF SCOTLAND	94	190	499	16

	COMMON BUZZARD	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	5	906	725	123.42
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	2	19	1	566.67
3	Coll, Tiree & the Western Isles	9	14	44	9.43
4	North West Seaboard	3	1	47	-4.00
5	The Peatlands of Caithness & Sutherland	0	10	48	20.83
6	Western Seaboard	3	3	56	0.00
7	Northern Highlands	2	1	50	-1.92
8	Western Highlands	0	0	31	0.00
9	North East Coastal Plain	0	31	10	310
10	Central Highlands	0	3	25	12.00
11	Cairngorm Massif	0	12	30	40.00
12	North East Glens	0	4	30	13.33
13	East Lochaber	1	2	23	4.17
14	Argyll West and Islands	1	12	76	14.29
15	Loch Lomond, Trossachs & Breadalbane	0	0	35	0.00
16	Eastern Lowlands	0	76	29	262.07
17	West Central Belt	0	24	32	75.00
18	Wigtown Machairs & Outer Solway Coast	0	14	5	280.00
19	Western Southern Uplands & Inner Solway	0	18	55	32.73
20	Border Hills	0	20	21	95.24
21	Moray Firth	0	4	26	15.38
	WHOLE OF SCOTLAND	21	268	674	36

KESTREL	Distribution 1970 - 2010			
	No. decreasing	No. increasing	No. stable	%change
ENGLAND & WALES	63	23	1638	-2
Shetland	1	1	0	0
North Caithness & Orkney	12	2	24	-28
Coll, Tiree & the Western Isles	12	16	12	17
North West Seaboard	17	5	22	-31
The Peatlands of Caithness & Sutherland	13	4	41	-17
Western Seaboard	11	7	44	-7
Northern Highlands	14	4	35	-20
Western Highlands	8	2	18	-23
North East Coastal Plain	2	0	39	-5
Central Highlands	2	1	23	-4
Cairngorm Massif	2	2	36	0
North East Glens	1	0	33	-3
East Lochaber	11	3	11	-36
Argyll West and Islands	22	5	61	-20
Loch Lomond, Trossachs & Breadalbane	7	0	28	-20
Eastern Lowlands	5	1	100	-4
West Central Belt	3	0	55	-5
Wigtown Machairs & Outer Solway Coast	4	1	15	-16
Western Southern Uplands & Inner Solway	3	1	69	-3
Border Hills	0	0	41	0
Moray Firth	4	1	26	-10
WHOLE OF SCOTLAND	217	79	2371	-11

	MERLIN	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	94	69	145	-10
1	Shetland	6	10	12	22
2	North Caithness & Orkney	4	6	9	15
3	Coll, Tiree & the Western Isles	8	26	19	67
4	North West Seaboard	6	20	15	67
5	The Peatlands of Caithness & Sutherland	1	26	26	93
6	Western Seaboard	6	14	14	40
7	Northern Highlands	11	21	11	45
8	Western Highlands	6	8	0	33
9	North East Coastal Plain	6	0	1	-86
10	Central Highlands	3	11	8	73
11	Cairngorm Massif	4	15	22	42
12	North East Glens	2	11	13	60
13	East Lochaber	5	6	3	13
14	Argyll West and Islands	17	9	12	-28
15	Loch Lomond, Trossachs & Breadalbane	5	16	6	100
16	Eastern Lowlands	11	10	2	-8
17	West Central Belt	13	6	2	-47
18	Wigtown Machairs & Outer Solway Coast	2	2	0	0
19	Western Southern Uplands & Inner Solway	23	7	16	-41
20	Border Hills	6	14	17	35
21	Moray Firth	6	3	0	-50
	WHOLE OF SCOTLAND	151	241	208	25

	PEREGRINE	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	6	783	98	747
1	Shetland	13	1	2	-80
2	North Caithness & Orkney	8	8	16	0
3	Coll, Tiree & the Western Isles	9	17	15	33
4	North West Seaboard	17	5	16	-36
5	The Peatlands of Caithness & Sutherland	11	7	22	-12
6	Western Seaboard	15	15	14	0
7	Northern Highlands	16	10	14	-20
8	Western Highlands	11	5	3	-43
9	North East Coastal Plain	0	19	0	Inf
10	Central Highlands	9	4	13	-23
11	Cairngorm Massif	2	9	25	26
12	North East Glens	1	13	8	133
13	East Lochaber	11	0	7	-61
14	Argyll West and Islands	13	22	37	18
15	Loch Lomond, Trossachs & Breadalbane	3	10	20	30
16	Eastern Lowlands	1	69	4	1360
17	West Central Belt	2	30	6	350
18	Wigtown Machairs & Outer Solway Coast	0	8	7	114
19	Western Southern Uplands & Inner Solway	4	29	18	114
20	Border Hills	2	25	7	256
21	Moray Firth	5	11	4	67
	WHOLE OF SCOTLAND	153	317	258	40

	TAWNY OWL	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	98	33	1524	-4
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	1	2	6	14
3	Coll, Tiree & the Western Isles	0	0	0	NA
4	North West Seaboard	6	5	14	-5
5	The Peatlands of Caithness & Sutherland	12	11	16	-4
6	Western Seaboard	17	8	15	-28
7	Northern Highlands	8	6	32	-5
8	Western Highlands	3	7	16	21
9	North East Coastal Plain	7	0	31	-18
10	Central Highlands	6	3	16	-14
11	Cairngorm Massif	8	3	22	-17
12	North East Glens	2	1	30	-3
13	East Lochaber	5	3	13	-11
14	Argyll West and Islands	16	7	44	-15
15	Loch Lomond, Trossachs & Breadalbane	6	4	25	-6
16	Eastern Lowlands	8	5	90	-3
17	West Central Belt	14	1	42	-23
18	Wigtown Machairs & Outer Solway Coast	6	0	11	-35
19	Western Southern Uplands & Inner Solway	11	1	58	-14
20	Border Hills	1	4	36	8
21	Moray Firth	2	0	27	-7
	WHOLE OF SCOTLAND	139	71	544	-10

	SHORT-EARED OWL	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	177	50	107	-45
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	12	2	20	-31
3	Coll, Tiree & the Western Isles	4	12	8	67
4	North West Seaboard	6	2	0	-67
5	The Peatlands of Caithness & Sutherland	19	6	15	-38
6	Western Seaboard	14	8	13	-22
7	Northern Highlands	11	4	3	-50
8	Western Highlands	8	2	1	-67
9	North East Coastal Plain	23	0	4	-85
10	Central Highlands	13	1	4	-71
11	Cairngorm Massif	11	4	13	-29
12	North East Glens	15	1	14	-48
13	East Lochaber	10	1	1	-82
14	Argyll West and Islands	20	11	22	-21
15	Loch Lomond, Trossachs & Breadalbane	7	3	16	-17
16	Eastern Lowlands	46	2	12	-76
17	West Central Belt	24	1	12	-64
18	Wigtown Machairs & Outer Solway Coast	4	2	1	-40
19	Western Southern Uplands & Inner Solway	42	4	12	-70
20	Border Hills	19	0	18	-51
21	Moray Firth	19	0	1	-95
	WHOLE OF SCOTLAND	327	66	190	-50

	MAGPIE	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	10	44	1654	2
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	1	0	Inf
3	Coll, Tiree & the Western Isles	0	0	0	NA
4	North West Seaboard	2	1	0	-50
5	The Peatlands of Caithness & Sutherland	0	4	0	Inf
6	Western Seaboard	3	5	0	67
7	Northern Highlands	5	1	0	-80
8	Western Highlands	0	0	0	NA
9	North East Coastal Plain	1	4	36	8
10	Central Highlands	4	2	3	-29
11	Cairngorm Massif	1	3	3	50
12	North East Glens	2	5	19	14
13	East Lochaber	1	2	0	100
14	Argyll West and Islands	10	5	4	-36
15	Loch Lomond, Trossachs & Breadalbane	5	6	4	11
16	Eastern Lowlands	5	55	35	125
17	West Central Belt	2	4	51	4
18	Wigtown Machairs & Outer Solway Coast	2	6	9	36
19	Western Southern Uplands & Inner Solway	6	30	32	63
20	Border Hills	4	18	11	93
21	Moray Firth	7	8	9	6
	WHOLE OF SCOTLAND	60	160	216	36

	JAY	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	51	64	1494	1
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	0	0	NA
3	Coll, Tiree & the Western Isles	0	0	0	NA
4	North West Seaboard	1	1	0	0
5	The Peatlands of Caithness & Sutherland	0	0	0	NA
6	Western Seaboard	0	5	0	Inf
7	Northern Highlands	0	22	1	2200
8	Western Highlands	0	13	0	Inf
9	North East Coastal Plain	0	17	0	Inf
10	Central Highlands	0	12	0	Inf
11	Cairngorm Massif	0	14	3	467
12	North East Glens	2	17	10	125
13	East Lochaber	2	8	6	75
14	Argyll West and Islands	5	16	18	48
15	Loch Lomond, Trossachs & Breadalbane	3	2	25	-4
16	Eastern Lowlands	1	47	49	92
17	West Central Belt	3	23	15	111
18	Wigtown Machairs & Outer Solway Coast	2	4	3	40
19	Western Southern Uplands & Inner Solway	1	13	41	29
20	Border Hills	0	23	8	288
21	Moray Firth	0	17	0	Inf
	WHOLE OF SCOTLAND	20	254	179	118

	JACKDAW	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	16	10	1692	0
1	Shetland	3	0	0	-100
2	North Caithness & Orkney	8	2	22	-20
3	Coll, Tiree & the Western Isles	3	0	1	-75
4	North West Seaboard	3	2	5	-13
5	The Peatlands of Caithness & Sutherland	4	10	22	23
6	Western Seaboard	13	4	17	-30
7	Northern Highlands	12	0	17	-41
8	Western Highlands	10	1	2	-75
9	North East Coastal Plain	0	0	41	0
10	Central Highlands	5	2	17	-14
11	Cairngorm Massif	9	0	23	-28
12	North East Glens	1	0	33	-3
13	East Lochaber	9	0	3	-75
14	Argyll West and Islands	16	6	60	-13
15	Loch Lomond, Trossachs & Breadalbane	8	0	24	-25
16	Eastern Lowlands	0	0	106	0
17	West Central Belt	1	1	56	0
18	Wigtown Machairs & Outer Solway Coast	0	2	18	11
19	Western Southern Uplands & Inner Solway	4	3	65	-1
20	Border Hills	2	1	38	-3
21	Moray Firth	0	0	30	0
	WHOLE OF SCOTLAND	111	34	600	-11

	CARRION CROW	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	1	26	1700	1
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	12	7	171
3	Coll, Tiree & the Western Isles	2	0	0	-100
4	North West Seaboard	3	6	2	60
5	The Peatlands of Caithness & Sutherland	1	25	14	160
6	Western Seaboard	4	11	0	175
7	Northern Highlands	2	21	15	112
8	Western Highlands	1	7	1	300
9	North East Coastal Plain	0	1	40	2
10	Central Highlands	4	6	14	11
11	Cairngorm Massif	6	5	30	-3
12	North East Glens	0	0	34	0
13	East Lochaber	3	7	5	50
14	Argyll West and Islands	8	30	30	58
15	Loch Lomond, Trossachs & Breadalbane	0	3	32	9
16	Eastern Lowlands	0	1	107	1
17	West Central Belt	0	0	58	0
18	Wigtown Machairs & Outer Solway Coast	0	1	19	5
19	Western Southern Uplands & Inner Solway	0	1	72	1
20	Border Hills	0	0	41	0
21	Moray Firth	0	2	28	7
	WHOLE OF SCOTLAND	34	139	549	18

	HOODED CROW	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	1	4	14	20
1	Shetland	1	0	45	-2
2	North Caithness & Orkney	7	2	41	-10
3	Coll, Tiree & the Western Isles	15	3	63	-15
4	North West Seaboard	1	0	50	-2
5	The Peatlands of Caithness & Sutherland	6	6	45	0
6	Western Seaboard	3	4	65	1
7	Northern Highlands	1	0	54	-2
8	Western Highlands	0	0	31	0
9	North East Coastal Plain	3	17	11	100
10	Central Highlands	10	2	14	-33
11	Cairngorm Massif	3	8	5	63
12	North East Glens	6	6	0	0
13	East Lochaber	0	0	26	0
14	Argyll West and Islands	2	2	90	0
15	Loch Lomond, Trossachs & Breadalbane	6	4	19	-8
16	Eastern Lowlands	2	5	1	100
17	West Central Belt	7	4	3	-30
18	Wigtown Machairs & Outer Solway Coast	0	2	0	Inf
19	Western Southern Uplands & Inner Solway	0	3	0	Inf
20	Border Hills	1	0	0	-100
21	Moray Firth	6	2	22	-14
	WHOLE OF SCOTLAND	80	70	585	-2

	RAVEN	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	7	542	525	101
1	Shetland	0	5	39	13
2	North Caithness & Orkney	3	13	32	29
3	Coll, Tiree & the Western Isles	5	5	67	0
4	North West Seaboard	1	1	49	0
5	The Peatlands of Caithness & Sutherland	3	14	41	25
6	Western Seaboard	3	6	62	5
7	Northern Highlands	2	5	48	6
8	Western Highlands	0	3	28	11
9	North East Coastal Plain	0	3	0	Inf
10	Central Highlands	3	4	20	4
11	Cairngorm Massif	1	9	30	26
12	North East Glens	2	6	12	29
13	East Lochaber	0	2	23	9
14	Argyll West and Islands	0	15	79	19
15	Loch Lomond, Trossachs & Breadalbane	0	1	34	3
16	Eastern Lowlands	0	50	15	333
17	West Central Belt	1	29	17	156
18	Wigtown Machairs & Outer Solway Coast	1	6	13	36
19	Western Southern Uplands & Inner Solway	1	19	48	37
20	Border Hills	0	19	22	86
21	Moray Firth	3	11	4	114
	WHOLE OF SCOTLAND	29	226	683	28

	ARCTIC SKUA	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	0	0	0	NA
1	Shetland	3	1	37	-5
2	North Caithness & Orkney	3	9	25	21
3	Coll, Tiree & the Western Isles	3	8	8	45
4	North West Seaboard	1	5	1	200
5	The Peatlands of Caithness & Sutherland	4	5	5	11
6	Western Seaboard	0	1	0	Inf
7	Northern Highlands	0	0	0	NA
8	Western Highlands	0	0	0	NA
9	North East Coastal Plain	0	0	0	NA
10	Central Highlands	0	0	0	NA
11	Cairngorm Massif	0	0	0	NA
12	North East Glens	0	0	0	NA
13	East Lochaber	0	0	0	NA
14	Argyll West and Islands	8	0	1	-89
15	Loch Lomond, Trossachs & Breadalbane	0	0	0	NA
16	Eastern Lowlands	0	0	0	NA
17	West Central Belt	0	0	0	NA
18	Wigtown Machairs & Outer Solway Coast	0	0	0	NA
19	Western Southern Uplands & Inner Solway	0	0	0	NA
20	Border Hills	0	0	0	NA
21	Moray Firth	0	0	0	NA
	WHOLE OF SCOTLAND	22	29	77	7

	GREAT SKUA	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	0	0	0	NA
1	Shetland	3	7	33	11
2	North Caithness & Orkney	1	18	19	85
3	Coll, Tiree & the Western Isles	0	17	8	213
4	North West Seaboard	0	12	3	400
5	The Peatlands of Caithness & Sutherland	0	1	2	50
6	Western Seaboard	0	14	0	Inf
7	Northern Highlands	0	0	0	NA
8	Western Highlands	0	1	0	Inf
9	North East Coastal Plain	0	0	0	NA
10	Central Highlands	0	0	0	NA
11	Cairngorm Massif	0	0	0	NA
12	North East Glens	0	0	0	NA
13	East Lochaber	0	0	0	NA
14	Argyll West and Islands	1	1	0	0
15	Loch Lomond, Trossachs & Breadalbane	0	0	0	NA
16	Eastern Lowlands	0	0	0	NA
17	West Central Belt	0	0	0	NA
18	Wigtown Machairs & Outer Solway Coast	0	0	0	NA
19	Western Southern Uplands & Inner Solway	0	0	0	NA
20	Border Hills	0	0	0	NA
21	Moray Firth	0	0	0	NA
	WHOLE OF SCOTLAND	5	71	65	94

	BLACK GROUSE	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	125	16	59	-59
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	0	0	0	NA
3	Coll, Tiree & the Western Isles	0	0	0	NA
4	North West Seaboard	4	1	1	-60
5	The Peatlands of Caithness & Sutherland	10	12	9	11
6	Western Seaboard	3	1	0	-67
7	Northern Highlands	1	18	25	65
8	Western Highlands	1	6	1	250
9	North East Coastal Plain	4	1	1	-60
10	Central Highlands	2	3	20	5
11	Cairngorm Massif	3	6	26	10
12	North East Glens	5	6	20	4
13	East Lochaber	4	9	10	36
14	Argyll West and Islands	18	11	34	-13
15	Loch Lomond, Trossachs & Breadalbane	1	2	31	3
16	Eastern Lowlands	23	1	11	-65
17	West Central Belt	24	0	13	-65
18	Wigtown Machairs & Outer Solway Coast	2	2	0	0
19	Western Southern Uplands & Inner Solway	28	0	33	-46
20	Border Hills	8	2	31	-15
21	Moray Firth	7	1	5	-50
	WHOLE OF SCOTLAND	148	82	271	-16

	GREY PARTRIDGE	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	551	18	979	-35
1	Shetland	0	0	0	NA
2	North Caithness & Orkney	5	0	2	-71
3	Coll, Tiree & the Western Isles	3	0	0	-100
4	North West Seaboard	0	0	0	NA
5	The Peatlands of Caithness & Sutherland	14	0	0	-100
6	Western Seaboard	0	0	0	NA
7	Northern Highlands	3	1	2	-40
8	Western Highlands	0	0	0	NA
9	North East Coastal Plain	10	0	31	-24
10	Central Highlands	12	0	1	-92
11	Cairngorm Massif	17	0	4	-81
12	North East Glens	17	0	15	-53
13	East Lochaber	0	0	0	NA
14	Argyll West and Islands	11	1	0	-91
15	Loch Lomond, Trossachs & Breadalbane	13	0	3	-81
16	Eastern Lowlands	13	1	93	-11
17	West Central Belt	39	2	14	-70
18	Wigtown Machairs & Outer Solway Coast	12	0	4	-75
19	Western Southern Uplands & Inner Solway	64	1	4	-93
20	Border Hills	24	0	17	-59
21	Moray Firth	7	1	21	-21
	WHOLE OF SCOTLAND	264	7	211	-54

	OYSTERCATCHER	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	43	495	444	93
1	Shetland	0	0	47	0
2	North Caithness & Orkney	3	0	48	-6
3	Coll, Tiree & the Western Isles	3	5	76	3
4	North West Seaboard	6	3	42	-6
5	The Peatlands of Caithness & Sutherland	7	0	51	-12
6	Western Seaboard	4	1	68	-4
7	Northern Highlands	13	1	37	-24
8	Western Highlands	2	1	26	-4
9	North East Coastal Plain	0	0	41	0
10	Central Highlands	1	0	27	-4
11	Cairngorm Massif	3	1	37	-5
12	North East Glens	0	0	34	0
13	East Lochaber	3	2	18	-5
14	Argyll West and Islands	4	2	88	-2
15	Loch Lomond, Trossachs & Breadalbane	1	0	34	-3
16	Eastern Lowlands	1	11	95	10
17	West Central Belt	1	5	52	8
18	Wigtown Machairs & Outer Solway Coast	0	0	20	0
19	Western Southern Uplands & Inner Solway	2	0	71	-3
20	Border Hills	0	0	41	0
21	Moray Firth	0	0	31	0
	WHOLE OF SCOTLAND	54	32	984	-2

	GOLDEN PLOVER	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	50	18	138	-17
1	Shetland	0	7	35	20
2	North Caithness & Orkney	13	2	19	-34
3	Coll, Tiree & the Western Isles	5	18	40	29
4	North West Seaboard	2	7	39	12
5	The Peatlands of Caithness & Sutherland	3	2	54	-2
6	Western Seaboard	12	6	32	-14
7	Northern Highlands	2	1	52	-2
8	Western Highlands	3	9	15	33
9	North East Coastal Plain	3	0	0	-100
10	Central Highlands	2	1	25	-4
11	Cairngorm Massif	1	0	41	-2
12	North East Glens	15	2	12	-48
13	East Lochaber	6	4	14	-10
14	Argyll West and Islands	24	5	8	-59
15	Loch Lomond, Trossachs & Breadalbane	14	1	15	-45
16	Eastern Lowlands	23	3	8	-65
17	West Central Belt	23	0	2	-92
18	Wigtown Machairs & Outer Solway Coast	2	0	0	-100
19	Western Southern Uplands & Inner Solway	31	0	17	-65
20	Border Hills	15	1	25	-35
21	Moray Firth	6	1	3	-56
	WHOLE OF SCOTLAND	205	70	456	-20

	LAPWING	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	299	20	1322	-17
1	Shetland	3	1	42	-4
2	North Caithness & Orkney	2	1	45	-2
3	Coll, Tiree & the Western Isles	8	4	53	-7
4	North West Seaboard	14	6	19	-24
5	The Peatlands of Caithness & Sutherland	8	0	48	-14
6	Western Seaboard	11	8	36	-6
7	Northern Highlands	22	3	22	-43
8	Western Highlands	16	2	3	-74
9	North East Coastal Plain	2	1	38	-3
10	Central Highlands	3	0	25	-11
11	Cairngorm Massif	5	1	35	-10
12	North East Glens	0	0	34	0
13	East Lochaber	16	1	3	-79
14	Argyll West and Islands	39	1	40	-48
15	Loch Lomond, Trossachs & Breadalbane	9	0	25	-26
16	Eastern Lowlands	8	0	97	-8
17	West Central Belt	10	0	48	-17
18	Wigtown Machairs & Outer Solway Coast	7	0	13	-35
19	Western Southern Uplands & Inner Solway	11	1	61	-14
20	Border Hills	4	0	37	-10
21	Moray Firth	2	0	28	-7
	WHOLE OF SCOTLAND	200	30	752	-18

	CURLEW	Distribution 1970 - 2010			
NHZ	Name	No. decreasing	No. increasing	No. stable	%change
0	ENGLAND & WALES	308	117	688	-19
1	Shetland	0	5	41	12
2	North Caithness & Orkney	2	4	42	5
3	Coll, Tiree & the Western Isles	27	15	21	-25
4	North West Seaboard	14	5	22	-25
5	The Peatlands of Caithness & Sutherland	7	0	52	-12
6	Western Seaboard	14	8	37	-12
7	Northern Highlands	20	5	25	-33
8	Western Highlands	10	0	17	-37
9	North East Coastal Plain	4	1	36	-8
10	Central Highlands	1	1	26	0
11	Cairngorm Massif	4	1	37	-7
12	North East Glens	1	0	33	-3
13	East Lochaber	12	0	11	-52
14	Argyll West and Islands	28	1	59	-31
15	Loch Lomond, Trossachs & Breadalbane	5	0	30	-14
16	Eastern Lowlands	16	3	82	-13
17	West Central Belt	5	1	49	-7
18	Wigtown Machairs & Outer Solway Coast	6	0	13	-32
19	Western Southern Uplands & Inner Solway	2	0	70	-3
20	Border Hills	0	0	41	0
21	Moray Firth	4	0	25	-14
	WHOLE OF SCOTLAND	182	50	769	-14

Appendix 12: Definitions of 'healthy' populations of predators and prey

Questionnaire respondents' definitions of 'healthy' populations of predators and prey species in upland and lowland systems in Scotland according to preference for local or scientific knowledge. Showing proportion of respondents within each knowledge group whose statements were coded under each definition. NB: some statements were coded under more than one definition. Source: questionnaire respondents, n=321.

Summary of definition	Definition	Type of knowledge preferred	
		Local knowledge (211)	Scientific knowledge (110)
Overall balance and/or sustainability	Predator-prey balance	33%	12%
	Sustainable or manageable predator-prey balance	22%	13%
	Self-sustaining populations	8%	26%
	Stable populations	8%	5%
	Sustainable predator-prey balance	6%	18%
	Maintain or increase biodiversity	4%	3%
	Good diversity of species	1%	2%
	Maximum numbers of both	0%	3%
Control predators and/or maintain or promote prey	Management of predators for protection of prey species	14%	1%
	Viable prey populations	8%	4%
	Reduced or controlled numbers of predators	7%	5%
	Increased numbers of prey species	7%	3%
	Return to previous prey population levels	3%	3%
	No prey population decline	3%	5%
	Harvestable or sustainable surplus	2%	3%
	To see prey species more often (greater diversity and numbers)	2%	4%

Limit impact of environmental/human factors on conservation effort	No artificial increase of non-native prey populations	0%	5%
	Cessation of illegal persecution of protected species	0%	3%
	Cessation of sport shooting	0%	1%
Ensure viability of rural economy and industries	Well managed and balanced grouse moor	0%	0%
	No negative economic impact on rural industry	1%	1%
Specifically pro-predator	Large numbers of predators	0%	1%
Other	Need to take a conservationist approach rather than preservationist	9%	0%
	Depends on the species of predator (e.g. generalist v specialist)	0%	2%
	Impossible to achieve healthy populations of both due to current ratios of certain predator species to prey	0%	2%
	Good land management will result in healthy populations	1%	0%
	Minimal populations	0%	1%
	Species should be native to the area	0%	1%
	Predators not adapting their feeding behaviour to seek out new prey targets	0%	1%
	Relates to recognised favourable conservation limits	0%	1%

Appendix S1 – S4

The following appendices are available as separate Excel spreadsheets. The first summarises information on the conservation status of all terrestrial wild bird species recorded in 10 or more 10km squares during Bird Atlas 2007-11. The other three summarise abundance change between Bird Atlas surveys for the whole of Scotland, by Natural Heritage Zones, and by land type. If you are interested in these, please send a request to Chris Werham at BTO Scotland, at the following email: chris.wernham@bto.org.

Appendix S1: Conservation status

S1 Conservation status.xls

Appendix S2: National population change

S2 National population change.xls

Appendix S3: NHZ abundance change

S3 NHZ abundance change.xls

Appendix S4: Abundance change by land type

S4 Abundance change by land type.xls