COMMISSIONED REPORT

Commissioned Report No. 278

The distribution of Mountain Hare (*Lepus timidus*) in Scotland (2006/07)

(ROAME No. R07AC308)

For further information on this report please contact:

Rob Raynor
Scottish Natural Heritage
Great Glen House
INVERNESS
IV3 8NW
Telephone: 01463-725 244
E-mail: robert.raynor@snh.gov.uk

This report should be quoted as:

Kinrade, V., Ewald, J., Smith, A., Newey, S., Iason, G., Thirgood, S. & Raynor, R. *(2008). The distribution of Mountain Hare (Lepus timidus) in Scotland (2006/07). Scottish Natural Heritage Commissioned Report No.278 (ROAME No. R07AC308).*

COMMISSIONED REPORT

Summary

The distribution of Mountain Hare (*Lepus timidus*) in Scotland (2006/07)

Commissioned Report No. 278 (ROAME No. R07AC308)

Contractor: Kinrade V, Ewald J, Smith A, Newey S, Iason G, Thirgood S & Raynor R

Year of publication: 2008

Background

The aim of this questionnaire-based survey was to assess the distribution of mountain hares in Scotland in 2006/07 and estimate the number of mountain hares taken for harvesting and population control purposes over the same time period. A secondary aim was to compare these data to similar data collected in 1995/96 (Tapper 1996) to establish any patterns of change in distribution and the level of take.

Main findings

- The area surveyed for mountain hares in 2006/07 was 71,098km^2, equivalent to 90% of the total area of Scotland.
- Mountain hares were present on 34,359km^2 (48%) of the surveyed area at the 10x10km level and absent from 36,739km^2 (52%).
- A total of 24,529 mountain hares were taken in 2006/07 across 90 estates, with the majority taken for the purposes of tick control (50%) followed by let/un-let shooting (40%) and forestry protection (10%). The total taken represents 7.0% of the 350,000 mountain hares estimated as the UK population in 1995 (Harris *et al.* 1995).

The following conclusions were reached:

- Of the area surveyed in both 1995/96 and 2006/07 there was no evidence that levels of take had reduced the range of mountain hares in Scotland.

For further information on this project contact:
Rob Raynor, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW
Tel: 01463–725 244
For further information on the SNH Research & Technical Support Programme contact:
Policy & Advice Directorate Support, SNH, Great Glen House, Leachkin Road, Inverness, IV3 8NW.
Tel: 01463 72500 or **pads@snh.gov.uk**

Acknowledgements

Thanks to Ronnie Kippen, Alan Hodgson, Davie Taylor, Sabine Dey, Stephen Tapper, Katie Hickey, Suzanne Richardson, Marc Edwards, James Connell, Neville Kingdon, Corinne Duggins, Peter Davey, Nicholas Aebischer, Nick Sotherton and Lucy Gilbert who all contributed support and helpful suggestions throughout the course of this project.

We would like to thank all those who contributed mountain hare sighting data, without which it would not have been possible to produce this report. Special thanks go to all the members of the Game & Wildlife Conservation Trust, the National Gamebag Census and The Scottish Gamekeepers Association who participated in the survey; governmental organisations including the Forestry Commission, Scottish Government Rural Payments and Inspections Directorate (SGRPID) and Scottish Natural Heritage (SNH), all of whom were extremely helpful; all the Not-for-Profit organisations who provided data including The National Trust for Scotland, RSPB, John Muir Trust, Clan Donald Lands Trust, Knoydart Foundation, The Woodland Trust and the Isle of Eigg Heritage Trust; the land management agents Bidwells and Smiths Gore; all those who shared mountain hare datasets including the BTO/JNCC/RSPB Breeding Bird Survey, the Highland Biological Recording Group and the Shetland Biological Records Centre; and the many members of the public who contributed incidental data.

Additional thanks go to Wildlife & Sporting artist Ashley Boon for providing a mountain hare watercolour as a raffle prize (and thanks to Liz Scott for organising this), similarly, thanks to the Edrington Group who provided two bottles of Famous Grouse Malt towards the raffle.

Table of Contents **Page**

LIST OF TABLES AND FIGURES....2
EXECUTIVE SUMMARY....3
1 INTRODUCTION....4
2 METHODS....7
2.1 Questionnaire design....7
2.2 Data entry and storage....10
2.3 Map production and analyses....11
2.4 Estate management....11
2.5 Data on the level of take....12
2.6 Statistical analysis....13
3 RESULTS....14
3.1 Information received....14
3.2 Survey area....14
3.3 Mountain hare distribution....18
3.4 Change in mountain hare distribution from 1995/96 to 2006/07....18
3.5 Mountain hare harvesting and population control....24
3.6 Mountain hare bag compared to the different estate types....24
3.7 Comparison with the level of take reported in 1995/96 (Tapper 1996)....26
3.8 Level of take and changes in mountain hare distribution on an estate basis....27
3.9 National Gamebag Census: trends in the level of take of mountain hares....28
4 DISCUSSION....30
4.1 Study design....30
4.2 Current distribution of mountain hares....30
4.3 Change in the distribution of mountain hares....31
4.4 Distribution and harvesting....31
4.5 Harvesting and population control of mountain hares....32
5 CONCLUSION....33
6 REFERENCES....35
APPENDICES....38

List of Tables **Page**

Table 1 Presence/absence of mountain hares at the 10x10-km square scale on an area basis in both the 1995/96 survey and the current survey.....19

Table 2 Number of mountain hares taken by all those estates that reported mountain hares taken (either on a seasonal or annual basis) during the period January 2006 or March 2006 to February 2007.....25

Table 3 Total numbers of mountain hares taken from January 2006 to February 2007 (seasonal and annual returns combined).....26

Table 4 Comparisons of the number of mountain hares taken between the 50 estates which were surveyed in common in 1995/96 and 2006/07.....27

Table 5 Comparisons (correlation analysis) between changes in mountain hare distribution on the estate level and the level of take.....28

List of Figures **Page**

Figure 1 Localities of all those mailed in the course of the survey.....9

Figure 2 The percentage area surveyed within each 10x10-km square in 2006/07.....15

Figure 3 The distribution of mountain hares in 2006/07 on a 10x10-km square basis.....16

Figure 4 Percentage of each 10x10-km square with mountain hares present in 2006/07.....17

Figure 5 Comparison between mountain hare distribution in 1995/96 (Tapper 1996) and 2006/07.....21

Figure 6 Mountain hare presence in 2006/07 compared to mountain hare presence in the past.....22

Figure 7 Comparison between the distribution of mountain hares in 1995/96 (Tapper 1996) and 2006/07.....23

Figure 8 Changes in mountain hare bag since 1960.....29

EXECUTIVE SUMMARY

1. The aim of this questionnaire-based survey was to assess the distribution of mountain hares in Scotland in 2006/07 and estimate the numbers of hares taken for harvesting and population control purposes over the same time period. A secondary aim was to compare these data to similar data collected in 1995/96 (Tapper 1996) to establish any patterns of change.
2. The area surveyed for mountain hares was 71,098km^2, equivalent to 90% of the total area of Scotland. This compares to 20,936km^2 (26%) covered in the questionnaire-based study in 1995/96.
3. Mountain hares were present on 34,359km^2 (48%) of the surveyed area at the 10x10km level and absent from 36,739km^2 (52%).
4. Estates managed for driven grouse shooting had the greatest percentage of area in which mountain hares were present (median = 63.8%, inter-quartile range: 34.0% - 89.6%), followed by estates managed for walked-up shooting (median = 8.8%, inter-quartile range: 0.6% - 47.9%) and estates with no grouse interest (median =0.0%, inter-quartile range: 0.0% - 5.5 %).
5. A total of 24,529 mountain hares were taken in 2006/07 across 90 estates, with the majority taken for the purposes of tick control (50%) followed by let/un-let shooting (40%) and forestry protection (10%). Of the total taken, 79% were shot, whilst 21% were snared. The greatest seasonal take of mountain hares was in winter (44%). The total taken represents 7.0% of the 350,000 mountain hares estimated as the UK population in 1995 (Harris *et al.* 1995).
6. There was no evidence that levels of take (analysed using mountain hare bag data received both from this survey and the National Gamebag Census (from 1995 to 2006)) reduced the range of mountain hares in Scotland. The impact of the level of take on the abundance of mountain hares cannot be investigated until abundance data over time becomes available.
7. It is suggested that future research should include regular monitoring of the mountain hare distribution within Scotland to ensure changes in the species range can be identified. Measures of abundance throughout the range of mountain hare are required to assess the current size of the Scottish mountain hare population. These measures of abundance should be used to further investigate the relationship between the level of take and changes in mountain hare abundance.

1 INTRODUCTION

The Scottish mountain hare, *Lepus timidus scoticus* (Hilzheimer 1906) is a subspecies of the mountain hare *Lepus timidus* and is native to the Highlands of Scotland. It is recognised as being genetically distinct from the Irish mountain hare (*Lepus timidus hibernicus*) (Corbet & Harris 1991) and is the UK's only native lagomorph species. Although widespread throughout Scotland, they are typically more numerous in central and eastern Scotland (Harris *et al.*. 1995). The early to mid twentieth century saw mountain hares introduced into many of the Scottish islands including Shetland, Orkney (Hoy), the Western Isles, Skye, Raasay, Scalpay, Eigg, Mull, Islay and Jura (Corbet & Harris 1991) and to areas of southern Scotland including Ayrshire, Lanarkshire and Peebleshire in the 1830s and 1840s (Yalden 1999). Although now known to be extinct from Eigg and Islay, mountain hares still remain in some of the introduced areas.

Distribution maps have been produced for mountain hares in Scotland using four different datasets in the past 15 years. Arnold (1993) published the first comprehensive distribution map based on Biological Records Centre (BRC) data from 1959 to 1991. In 1996, Tapper published information on the occurrence (presence or absence) and management of mountain hares reported by respondees to a postal questionnaire of shooting estates within the Game & Wildlife Conservation Trust's National Gamebag Census (NGC) (Appendix 1). Newson & Noble (2005) used data collected on mammals from the British Trust for Ornithology's (BTO) Breeding Bird Survey (BBS) to highlight changes in the abundance of mountain hares between 1995 and 2002 and to identify areas of mountain hare presence. There has also been a smaller-scale study of mountain hare distribution within the Southern Uplands of Scotland (The Wildlife Partnership 2005), which gathered both historic and recent information from a variety of sources regarding mountain hare presence/absence and abundance data for all the upland 10x10-km squares within the Southern Uplands.

In addition to mapping the distribution of mountain hares, there has been one published estimate of the size of the Scottish mountain hare population. Harris *et al.* (1995) estimated that the UK mountain hare population was in the region of 350,000 individuals, with Scotland containing 99% of the UK population. This calculation was based upon the relative abundance of mountain hares in optimum and sub-optimum habitat in comparison to the occurrence of this habitat throughout Scotland. The study recognised that this estimate may be either overestimated or underestimated by up to 50% owing to the limited distribution and abundance data available for this species.

With only one recent estimate of UK mountain hare population size (Harris *et al.* 1995), it is not surprising that there are varying accounts of changes in abundance over recent years

(Tapper 1992; Newson & Noble 2005). Analysis of the numbers of mountain hares by Newson & Noble (2005) suggests that mountain hares within Britain may have been in decline since 1997. Earlier work based on bag data from shooting estates also indicated there may have been declines in the Scottish population (Tapper 1992); analysis of NGC game bag records demonstrated that the average bag for mountain hares was significantly lower in many areas of Scotland from 1961 to 1985 than it was from 1900 to 1938. However, more detailed analysis of NGC bags suggests that approximately 50% of mountain hare populations in Scotland may demonstrate cyclic population dynamics (Reynolds *et al*. 2006, Newey *et al.* 2007a). These cyclic dynamics may complicate analysis of long-term patterns of abundance. The factors causing fluctuations and long term changes in the numbers and distribution of this species remain unknown.

Mountain hares are potentially under threat from a combination of factors including habitat loss, habitat fragmentation, change in habitat management and local over-exploitation (Harris *et al.*. 1995; Macdonald *et al.* 1998). High densities of mountain hares are often associated with heather moorland managed for red grouse *Lagopus lagopus scoticus.* The habitat management and predator control for grouse production are thought to benefit mountain hares (Hewson 1984). If so, the loss of heather moorland in association with declines in sport shooting and afforestation are likely to have had a negative effect on mountain hare distribution and numbers (Harris *et al.*. 1995; Macdonald *et al.* 1998; Thompson *et al*. 1995). Recent studies from Sweden hypothesise that where mountain hares overlap with brown hares (*Lepus europaeus*) they may suffer from hybridisation and competition from the brown hare (Thulin 2003).

In addition to being an important quarry species, mountain hare numbers are controlled to protect forestry, woodland and crops (Tapper 1992, 1996; Hewson 1970) and as a management practice to promote red grouse populations. Mountain hares carry sheep ticks which are vectors for louping-ill, a viral disease affecting red grouse and other animals, but which does not affect mountain hares (Hudson *et al.* 1998; Gilbert *et al.* 2001). Theoretical studies show that via this route, mountain hares can aid louping ill virus persistence and red grouse populations may be negatively affected by mountain hares only in the near absence of alternative tick hosts such as deer and when louping ill prevalence is very high (Gilbert *et al.* 2001, Laurenson *et al.* 2003). An empirical study under which these circumstances were met found that taking hares increased the number of young per female grouse but did not support a negative association between mountain hare and red grouse population densities (Laurenson *et al.* 2003). The role of mountain hares in mediating limitation of red grouse populations via tick-borne louping ill has been questioned (Cope *et al.* 2004, Laurenson *et al.* 2004). There is growing concern about the effects of perceived large-scale culls of

mountain hares to control ticks and louping ill. However, very little information is currently available on the level of harvest or current management of mountain hares.

In summary, there is some suggestion that mountain hare numbers in Scotland have declined in recent years along with a decline in distribution; however, the extent of this decline and whether this represents a long-term trend or is merely the low phase of a population cycle is unknown. Mountain hares are listed in Annex V of the EC Habitats Directive (1992), as a species *'of community interest whose taking in the wild and exploitation may be subject to management measures'*. Member States are therefore required to ensure that the conservation status of mountain hares is good and that their populations are managed sustainably. Against this backdrop, Scottish Natural Heritage (SNH) and Scotland's Moorland Forum have expressed concern that there are no reliable estimates of mountain hare abundance to the extent that SNH have added mountain hares to their Biodiversity Action Plan list.

A joint report by SNH, The Game Conservancy Trust (since renamed the Game & Wildlife Conservation Trust) and Macaulay Institute (Newey *et al.* in press) determined that an assessment of mountain hare distribution and abundance was necessary to inform management of the Scottish mountain hare population. Newey *et al.* (in press) suggested undertaking questionnaire surveys of land owners, managers, and gamekeepers to assess the current distribution of mountain hares in Scotland and the level of harvest categorised by reason, method, season and region. This report is the outcome of that concept, the results of which are likely to form the basis of further studies into the key factors affecting mountain hare numbers and distribution in Scotland.

2 METHODS

2.1 Questionnaire design

The questionnaire used by Tapper (1996; Appendix 2) formed the basis of the one used in this survey to obtain the information necessary to map the distribution of mountain hare and examine the levels of harvest and control. To maximise survey coverage, the questionnaire was mailed to estates (including individuals who manage farms, shooting estates and non-shooting estates; Appendix 3i) and organisations (including Not-for-Profit (NfP) organisations or governmental bodies who own or manage land in Scotland; Appendix 3ii). In addition, a questionnaire leaflet was designed to allow for casual reports by individuals who had made incidental sightings of mountain hares (Appendix 3iii).

Along with the questionnaire, a 1:50,000 scale map centred on participants' postcodes was provided and participants were asked to indicate the 1x1-km squares in which mountain hares had been observed between March 2006 and October 2007. In addition, the questionnaires requested information on the number of mountain hares taken (from March 2006 to February 2007) including a breakdown by method and reason. Specifically, participants were asked for the numbers taken for let/commercial/formal shooting (organised shoots) and un-let/informal shooting (shot by keeper and colleagues, as per Tapper 1996), forestry protection and tick control.

With a focus on estates, the questionnaire was mailed to all individuals included in the membership databases of the Game & Wildlife Conservation Trust (hereafter referred to as the Trust), the National Gamebag Census (NGC) and the Scottish Gamekeepers Association (SGA). Most private estate owners and gamekeepers/stalkers within Scotland hold membership of one or more of these organisations so a large proportion of privately owned estates are considered to have been surveyed by mailing these members. In addition, further contact details for a number of private land owners who do not hold membership with either the Trust, NGC or SGA but own large areas of land were identified through the Who Owns Scotland website (www.whoownsscotland.org.uk) and its associated publication (Wightman 1996) and included in the questionnaire mailing.

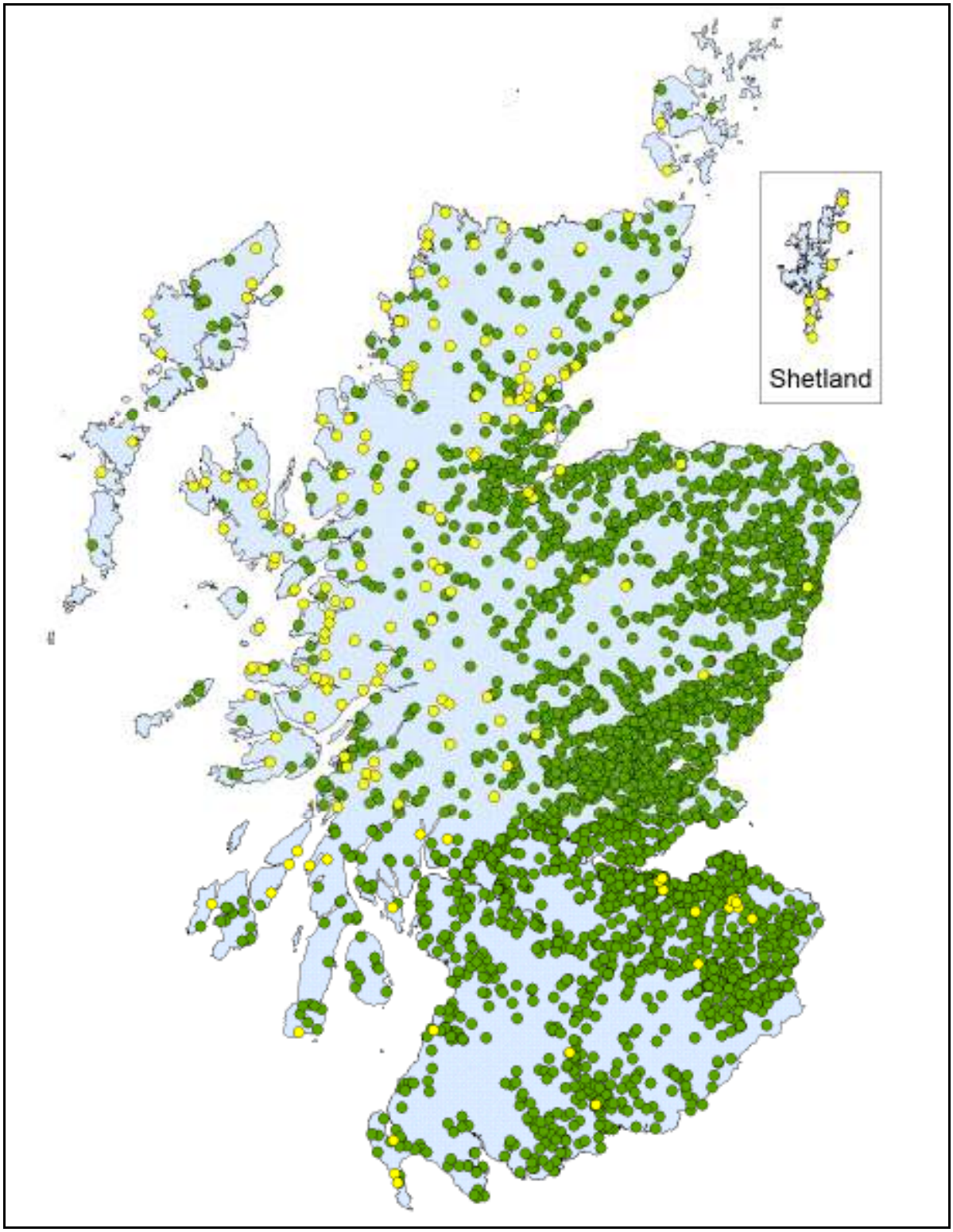
The organisations contacted were comprised of NfP organisations and governmental bodies. It was important to include these organisations in the survey as NfP organisations are estimated to own over 6% of land (266,407 ha) within the Highlands and Islands of Scotland, whilst governmental bodies own 625,458 ha of land (8%) across Scotland as a whole (Wightman 1996; Forestry Commission 2007). As there are a large number of NfP organisations which vary greatly in the size of their land holding, the survey was limited, for

efficiency reasons, to those that owned a substantial proportion of land; this accounted for 85% of the total land owned by NfP organisations. Contact addresses for these organisations were obtained from Wightman (2001). The governmental bodies contacted for participation in the survey include the Forestry Commission, the Scottish Government Rural Payments and Inspections Directorate (SGRPID), Scottish Natural Heritage and Defence Estates (the land-owning division of the Ministry of Defence). A list of the NfP organisations and governmental bodies contacted, along with the area of land owned by these organisations, can be found in Appendix 4.

In total, 3,873 questionnaires were posted to the above groups. The first mailing was followed by a reminder letter which was sent to members of both the Trust and the NGC. Reminders (1,224) were sent only to those who had not returned survey forms and were associated with land either in an upland area or land which was within a 10x10-km British National Grid square for which no survey form with a boundary had been received. After accounting for duplicate forms, 3,390 mailed questionnaires were considered to be the baseline numbers of all those mailed and was used in the final analysis.

The geographical spread of those contacted covered all areas where mountain hares have been recorded in the past (Figure 1). The localities of those contacted through the membership databases (the Trust, NGC and SGA) reflect the strong grouse moor interest of these groups. Estates outwith the Trust, NGC and SGA membership (*i.e.* additional estates identified along with NfP and governmental estates) provided coverage in the western Scottish mainland and the islands.

Figure 1 *Localities of all those mailed in the course of the survey. Green dots denote the Trust, NGC and SGA members, whilst yellow dots highlight the additional estates found along with the NfP and governmental estates contacted.*



In addition to those mailed, various conservation, wildlife and hill-walking organisations operating within Scotland were contacted (Appendix 5) to advise them of the survey and to request that they inform members and employees of its details. To inform tourists about the survey and encourage them to contribute mountain hare sightings, a survey poster was created (Appendix 6) and mailed to the Scottish tourist information centres (excluding the Central Belt). Additional posters were mailed to the Loch Lomond & The Trossachs National Park for display around the park. Posters were not sent to the Cairngorms National Park as all estate owners within this area had been mailed using the membership databases. The survey was further publicised by drawing attention to survey details on the Game & Wildlife Conservation Trust website, with articles printed in a number of newspapers and magazines (Appendix 7).

2.2 Data entry and storage

Data received with regard to mountain hare presence/absence, numbers shot and additional notes were entered and stored in Microsoft Access 2007. The map data received were captured using MapInfo (Mapinfo Corporation, v9.0.1) and estate boundaries digitised using the heads-up[1] method. In cases where participants had noted mountain hare presence/absence on their estate/land but had not provided a boundary, an attempt was made to find it by reference to a previously digitised MapInfo file of estate boundaries from the Who Owns Scotland website (www.whoownsscotland.org.uk). Where estate boundaries could not be found, the 1x1-km grid which contained the participant's geo-referenced postcode was digitised and added to the study.

The information on the presence and absence of mountain hares was recorded in MapInfo on a 1x1-km grid map covering Scotland. Initially all grid squares were set to non-surveyed. The digitised boundaries were overlain on this grid and all 1x1-km squares which fell within each boundary were marked as surveyed and updated to reflect whether or not mountain hares were present. Where boundaries bisected a 1x1-km square, mountain hare presence/absence data for that particular square was updated only if greater than half the square fell within the estate boundary or if it was reported to be positive for mountain hares by the participant. The casual reports received were also recorded on the 1x1-km grid map.

[1] Heads-up digitising in this instance involved manually tracing the outline of estate boundaries submitted on the geo-referenced raster 1:50,000 OS map (Crown Copyright all rights reserved License 100020577).

2.3 Map production and analyses

The total area surveyed for mountain hare was calculated as the total area covered within the combined estate boundaries. This ensured that areas of overlapping boundaries (possible due to errors in the tracing of estate boundaries by respondents or overlap in areas covered by gamekeepers etc.) were not counted twice. Maps were then produced at the 10x10-km square level (to maintain estate anonymity and minimise small-scale errors of location in the returned maps). Mapping at this level was used to present the following information:

- The percentage area surveyed throughout the course of the study
- Mountain hare distribution within Scotland
- The percentage of each 10x10-km square in which mountain hares were present
- Changes in the distribution of mountain hares from 1995/96 to the present study

To assess the percentage area surveyed within each 10x10-km square, the digitised estate boundaries were combined and intersected by the 10x10-km squares. The resulting surveyed area within each 10x10-km square was expressed as a percentage of the square. This calculation took into account the coastal regions where the areas of the 10x10-km squares were less than 100 km^2.

Changes in the distribution of mountain hares within each 10x10-km square were investigated by comparing the 2006/07 distribution with the findings of the report by Tapper (1996). The change in mountain hare distribution was measured as the area where mountain hares were reported in 2006/07 but not in 1995/96 minus the area where mountain hares were reported in 1995/96 but not in 2006/07, expressed as a percentage of the area of an estate or 10x10-km square. If the area where mountain hares were present in 1995/96 but not in 2006/07 was greater than the area in which they were present in 2006/07 but not in 1995/96 then this would result in a negative value, indicating a relative loss in mountain hare distribution on that estate or square. This method of measuring change obscures small scale shifts in distribution (within each 10x10-km square).

2.4 Estate management

The mountain hare distribution from this study was compared to areas of actively managed grouse moors across Scotland to assess whether there was any correlation between mountain hare presence, change in mountain hare distribution and the intensity of grouse moor management. The boundaries of grouse moors were collated by the Trust using data collected from a previous postal survey and abstracted from the NGC, along with

advertisements for grouse shooting. Grouse moors were divided into those which harvest grouse by driven shooting (hereafter referred to as driven grouse moors) or walked-up shooting (those which harvest grouse by walking guns in a line or shooting over dogs, hereafter referred to as walked-up grouse moors). Estates which do not shoot grouse and therefore undertake very little heather management or predator control were also included in the analyses and are referred to as non-grouse moors.

2.5 Data on the level of take

Data on the level of take, including the reasons for the taking of mountain hares (let/un-let shooting; forestry/crop protection; tick control) along with the numbers taken by season and method (shooting or snaring) were recorded in Microsoft Access 2007. Respondents provided varying amounts of information on the number of mountain hares taken; some provided the numbers taken seasonally in addition to the annual figure, whilst others recorded only seasonal data or annual data. To ensure no duplication in the calculation of the total numbers taken, a distinction was made between respondents that provided only seasonal data and those that returned annual data. Where participants had provided seasonal and annual data, the seasonal data were used in all cases with the exception of one estate where the annual figure was used because it was considerably higher than the combined seasonal figure. Mountain hare bags were calculated as the number of mountain hares taken divided by the area where mountain hares were reported as present on that estate (as per Tapper 1996). Several measures of mountain hare bags (let/un-let shooting, forestry, tick and total bag) were used to examine the relationship between the changes in local distribution with the local levels of take in 2006/07 at the estate level. Estates which indicated that no mountain hares were taken in 1995/96 and 2006/07 were also included in the analysis, though only estates with > 1 km^2 surveyed in common in both 1995/96 and 2006/07 were included.

Similarly, information recorded in the National Gamebag Census (Tapper 1992, Davey & Aebischer 2008) detailing the number of mountain hares harvested on shooting estates in Scotland from 1995/96 to 2006/07 was used to examine the relationship between the changes in local distribution during this period with the local levels of take. The average mountain hare bag (number of mountain hares taken divided by the area (km^2) of moorland within an estate) was used and the analysis was restricted to those estates or 10x10-km squares which were surveyed in 1995/96 and had submitted mountain hare bag data to the NGC from 1996 to 2006.

2.6 Statistical analysis

The percentage area of the different types of estates where mountain hares were found was compared using Kruskal-Wallis One-way Analysis of Variance due to the large number of estates either covered by mountain hare distribution or, conversely, where no mountain hares were found. This analysis was restricted to those estates greater than 1 km^2 in size and the statistics presented for each type of estate was the median and inter-quartile range. The differences in the mountain hare bag between different types of estates was compared using a Generalized Linear Model (GLM) (McCullagh & Nelder 1996) with a Poisson error distribution and logarithmic link function, with the number of mountain hares taken as a response variable and the logarithm of the area where hares were found on an estate as an offset variable. The change in hare distribution on different types of estates was compared using Kruskal-Wallis One-way Analysis of Variance. The Kruskal-Wallis analyses were restricted to those estates greater than 1 km^2 in size and to those estates with more than 1 km^2 in common between the two surveys (1995/96 and 2006/07).

Spearman Rank correlation analysis was used to examine the relationship between changes in mountain hare distribution and the average mountain hare bag from 1995/96 to 2006/07 using (i) NGC data expressed as mountain hare bag and (ii) the number of mountain hares reported taken in this survey. This analysis was carried out at the estate level. Bonferroni corrections were used to examine the results for significance which required a p-value < 0.005 for significance.

Annual indices (± se) of the mountain hare bag from the NGC were obtained from Davey & Aebischer (2008). The approach is described in Appendix 9.

All analyses were carried out using Genstat 10.2 (Lawes Agricultural Trust, Rothamsted).

3 RESULTS

3.1 Information received

A total of 918 questionnaires were returned (27% of those sent) of which 640 provided estate boundaries. Of the 278 which did not provide boundaries, 71 boundaries were found using the Who Owns Scotland estate boundary information. Of the questionnaires returned, 306 (33%) reported some mountain hare presence, whilst 550 (60%) reported an absence of mountain hares. The remainder (7%) either gave no information at all or could not provide information as they did not own or manage land. In addition to the questionnaires returned, incidental reports of mountain hare presence were received from 42 hill-walkers and NGO land managers providing mountain hare sightings on a total of 144 1x1-km squares, whilst the Forestry Commission confirmed mountain hare presence across 39 km^2 of their Scottish forest estates. Finally, mountain hare sighting data from 2006 were provided by the Biological Records Centre (10 sightings) and the BTO Breeding Bird Survey (15 sightings).

3.2 Survey area

The total area surveyed was 71,098 km^2 (at the 10x10-km square level) equating to 90% of the total area of Scotland (the total area of Scotland on the mapping software used was 79,199 km^2). This included 95% of Scotland's upland area (land above 300 m). The majority of the area surveyed (98%) was made up of returns from estates (641) greater than 1 km^2 in size. The majority of these estates (504) were not grouse moors and covered an area of 16,161 km^2 (62% of the area from estates), whilst driven grouse moors (88 estates) contributed an area of 5,089 km^2 (19%) and walked-up grouse moors (48 estates) accounted for 4,463 km^2 (17%). The percentage area surveyed within each 10x10-km square was calculated and split into four ranges: 0-10, 10-40, 40-70 and 70-100% (Figure 2). The most surveyed areas (> 70% surveyed) are in the Central and Eastern Highlands and the Northwest Highlands, together with the islands of Arran, Islay, Eigg, Coll, Tiree, Barra, the Uists, Benbecula, Orkney and Yell, Unst and Fetlar in Shetland.

Figure 2 The percentage area surveyed within each 10x10-km square in Scotland in 2006/07.

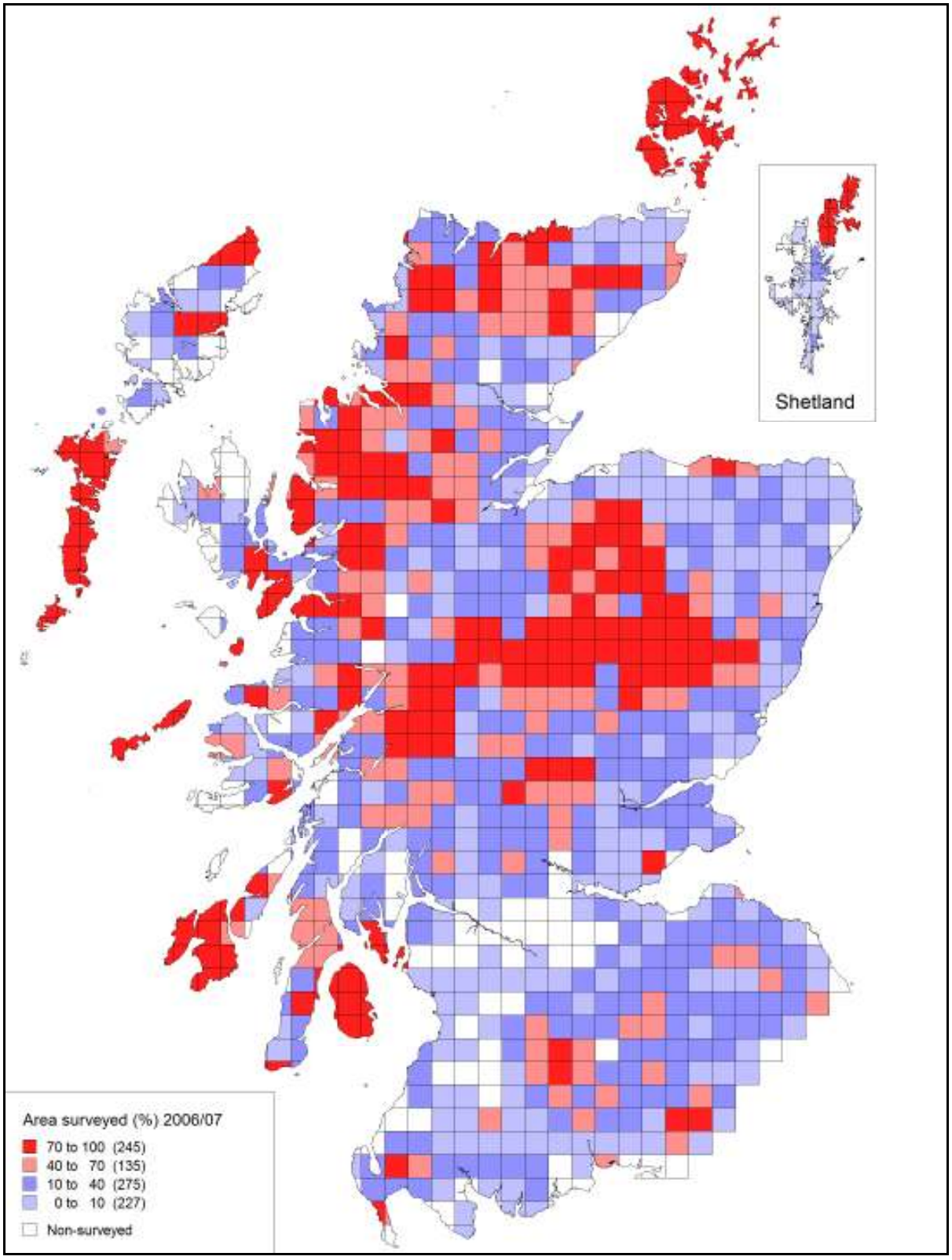


Figure 3 *The distribution of mountain hares in 2006/07 in Scotland on a 10x10-km square basis. The use of a 10x10-km square scale resulted in some areas appearing to have mountain hares when in fact they were reported as absent. They are (from north to south) Yell (Shetland), Mainland (Orkney), the Morvern peninsula (adjacent to Mull) and Islay.*

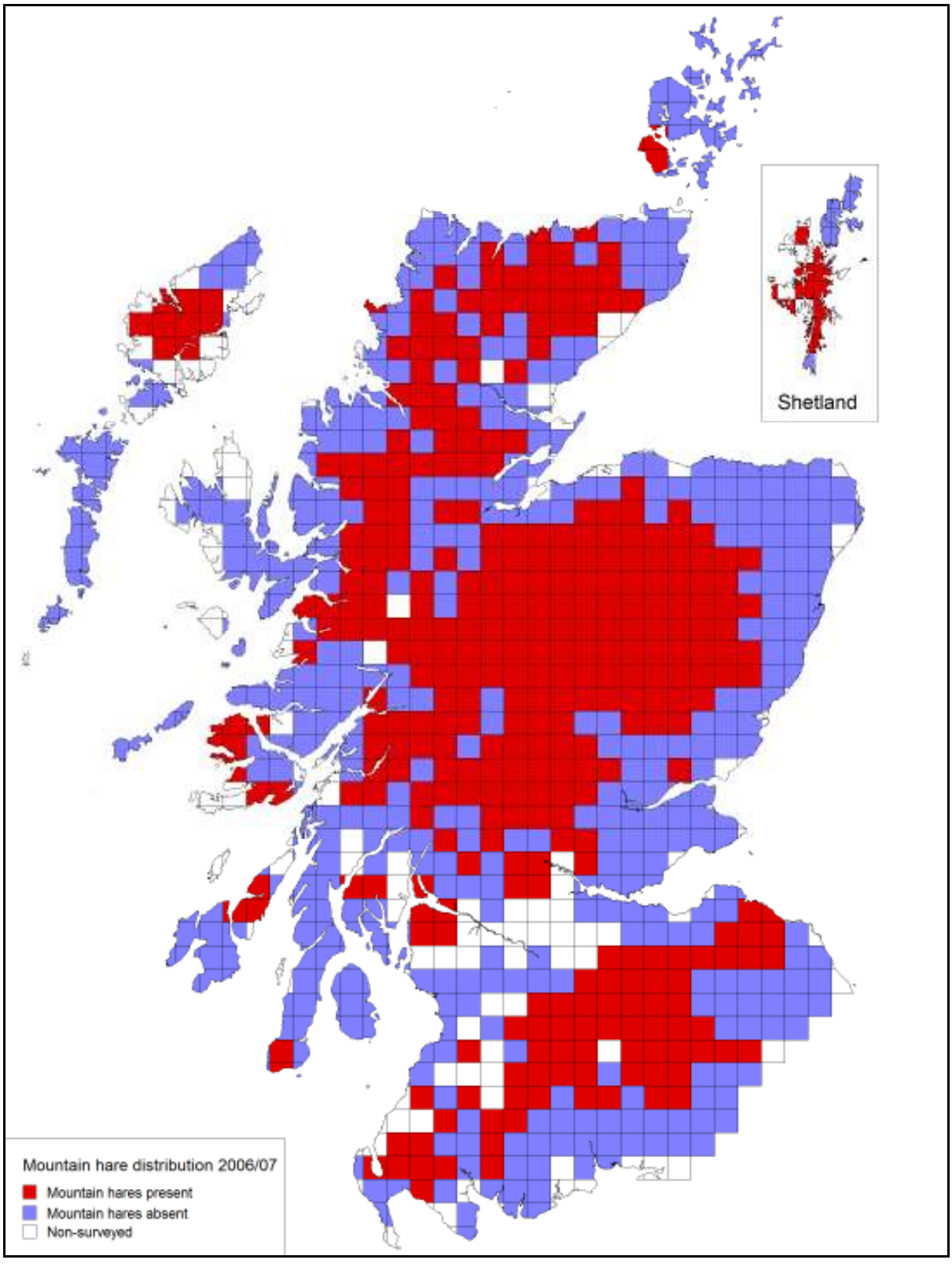
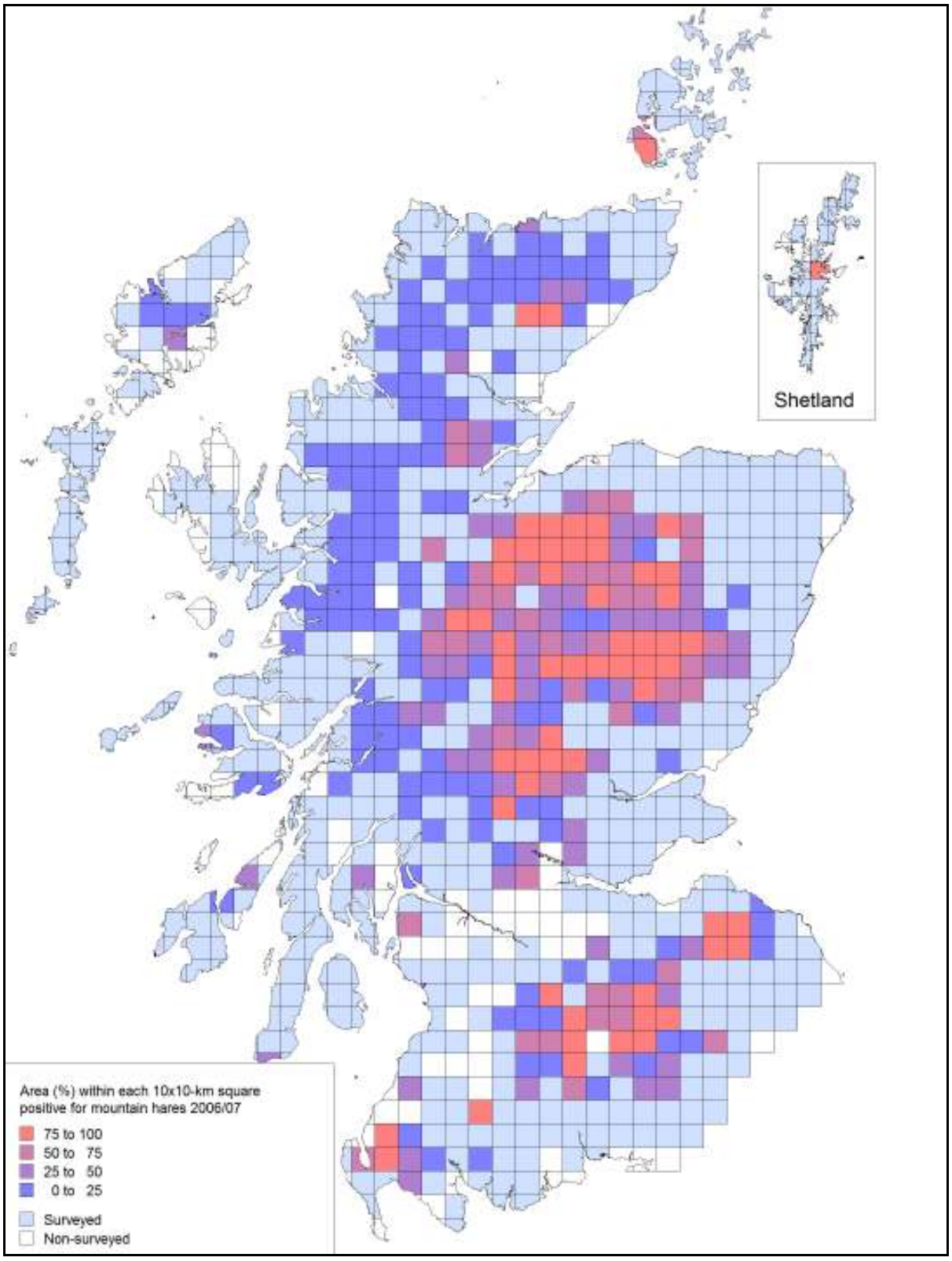


Figure 4 *Percentage of each 10x10-km square with mountain hares present in Scotland in 2006/07. The percentage presence was calculated only for the 10x10-km squares where >10 km^2 was positive for mountain hares. Squares with <10 km^2 mountain hare presence are marked as surveyed (light blue).*



3.3 Mountain hare distribution

The areas of mountain hare presence and absence across Scotland were recorded and displayed at the 10x10-km scale (Figure 3). Within the area surveyed, mountain hares were present on 34,359 km^2 (48%, calculated at the 10x10-km square level) and recorded as absent from 36,739 km^2 (52%). The areas of mountain hare presence do not provide any information on mountain hare distribution within each 10x10-km square. To address this, the percentage area of mountain hare presence within each 10x10-km square was calculated and is presented in Figure 4. This indicated that in the northeast of Scotland mountain hare distribution was most widespread (75-100% presence in many 10x10-km squares). In the south of Scotland, mountain hares appeared to be locally common in some areas but the total area occupied within each 10x10-km square was considerably less than in the northeast. Although mountain hares were found throughout the Northwest and Northern Highlands of Scotland, their distribution within each 10x10-km square was sparse (<25% presence in the majority of squares) and they were common in only a few 10x10-km squares.

The estates that returned information regarding mountain hare presence within their boundaries differed in the percentage of their area occupied by mountain hares (Kruskal-Wallis $H = 186.2$, $P < 0.001$). Estates with driven grouse moors had a greater percentage of their area occupied by mountain hares (median = 63.8%, inter-quartile range: 34.0% - 89.6%) than walked-up grouse moors (median = 8.8%, inter-quartile range: 0.6% - 47.9%) and estates that did not manage their land for grouse (median = 0.0%, inter-quartile range: 0.0% - 5.5 %).

3.4 Change in mountain hare distribution from 1995/96 to 2006/07

The distribution of mountain hares in 2006/07 was compared with that recorded in 1995/96 (Tapper 1996) at the 10x10-km square level (Table 1). The 1995/96 study surveyed an area of 20,936 km^2, of which 20,462 km^2 (98%) was surveyed in 2006/07 along with an additional 50,636 km^2. Of the area surveyed in 1995/96, mountain hares were present on 14,600 km^2 (70%) in 1995/96 as opposed to 14,180 km^2 (67%) in 2006/07. In addition, mountain hares were reported as consistently present in 59% of this same area and consistently absent in 20%. Lastly, in 2006/07 mountain hares were present in 29% of the area in which they were absent in 1995/96, whilst they were absent from 14% of the area in which they were present in 1995/96. The mapped comparisons of the area surveyed in Tapper's (1996) study and the current study (on a 10x10-km square basis) highlight 21 10x10-km squares with

mountain hare presence in 1995/96 but not in 2006/07 and 19 10x10-km squares where mountain hares were present in 2006/07 but not in 1995/96 (Figure 5).

Table 1 The area of mountain hare presence and absence in Scotland at the 10x10-km square scale in both the 1995/96 survey (Tapper 1996) and the current 2006/07 survey.

1995/96 survey	**Area (km^2)**	**2006/07 survey**	**Area (km^2)**
Present	14,600	Present	12,320
		Absent	1,999
		Not surveyed	282
Absent	6,336	Present	1,860
		Absent	4,283
		Not surveyed	193
Not surveyed	58,263	Present	20,179
		Absent	30,457
		Not surveyed	7,626

In addition to the changes in distribution highlighted through comparison with the 1995/96 study, a number of respondents to the 2006/07 survey indicated that mountain hares were no longer found in areas where they had been observed in the past. This information was included in an overall comparison of the areas where mountain hares were present in 2006/07 versus those areas where they were present either in the past (as indicated by respondents) or in 1995/96 but are now absent (Figure 6). An examination of figures 5 and 6 indicates that the squares that vary appear to be on the edge of the known "range" of the species.

The comparative loss of mountain hare distribution was investigated through direct comparisons of the 1x1-km squares surveyed in both 1995/96 and 2006/07 and where mountain hares were identified as being present in either 1995/96 or 2006/07, the results of which are displayed at the 10x10-km square level in Figure 7. This figure indicates where mountain hare distribution has increased, decreased or experienced <10% change in distribution overall (on a 1x1-km square basis) within each 10x10-km square. The 10x10-km squares which either had less than 10 km^2 surveyed in common in both 1995/96 and 2006/07, or had no mountain hare presence in both surveys were not included in the analysis (shown in light blue in Figure 7). It was suspected that some estates which had mountain hare presence had marked all the land within their estate as having mountain hares present rather than picking out the specific 1x1-km squares where the hares would normally be found. This 'blanket coverage' is believed to have been applied to two estates in 1995/96 but not in those same estates in 2006/07 and vice versa on one estate. As a

result, the spatial comparison in these particular estates may have given spurious decreases or increases over the last decade and so the 10x10-km squares (7 squares in total, highlighted in yellow on Figure 7) were included in the analysis as areas of <10% change in distribution. The total number of mountain hares taken across these three estates in 2006/07 was <5.

There was no significant difference in the percentage area occupied by mountain hares from 1995/96 to 2006/07 between the three types of estates (driven, walked-up and non-grouse moors) (Kruskal-Wallis $H = 175.5$, $P < 0.001$).

Figure 5 *Comparison between mountain hare distribution in Scotland in 1995/96 (Tapper 1996) and 2006/07 on a 10x10-km square basis.*

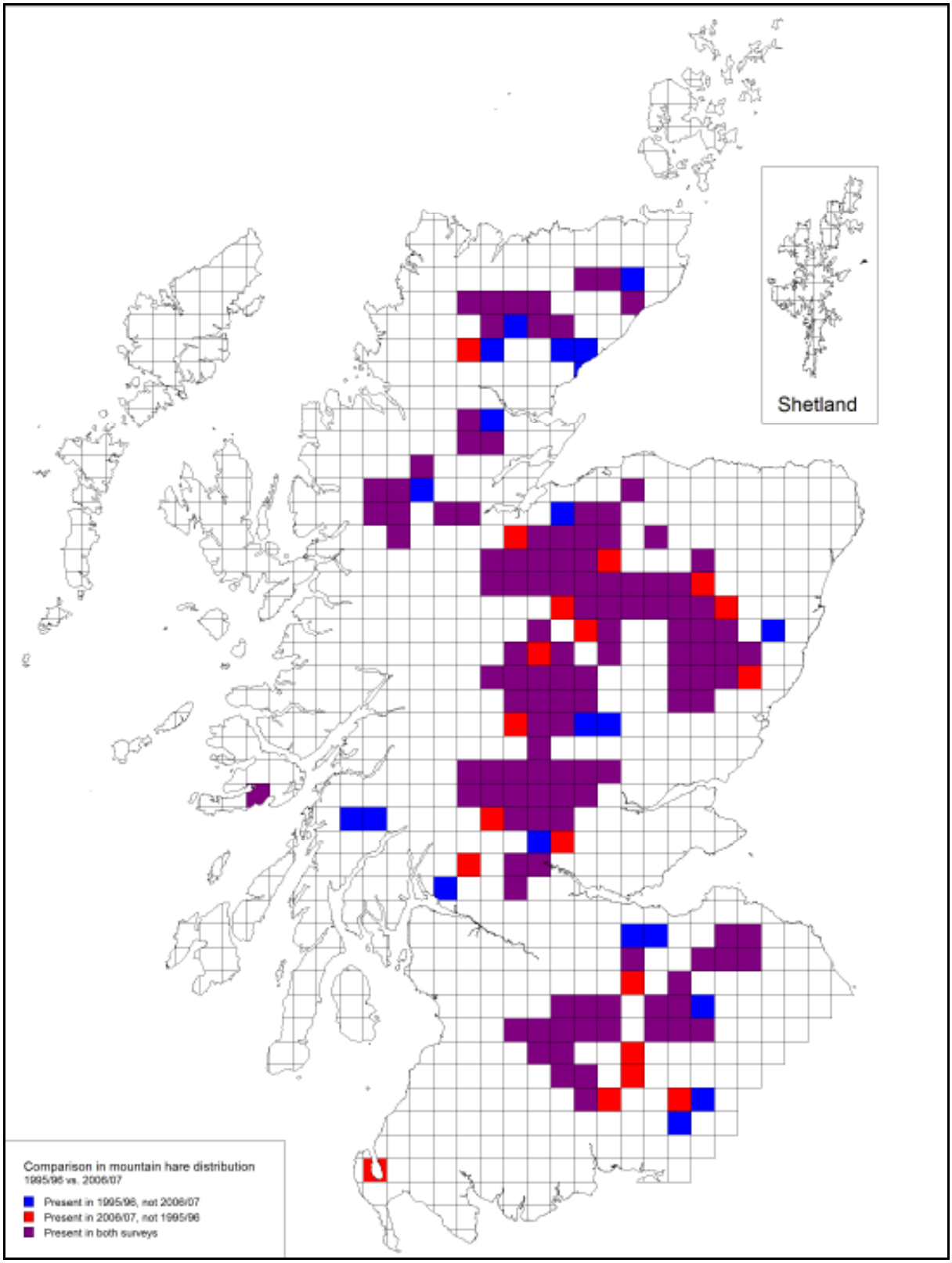


Figure 6 *Mountain hare presence in Scotland in 2006/07 (red) with areas where respondents indicated they were present in the past but absent in 2006/07 (light blue) and where mountain hares were present in 1995/96 but absent in 2006/07(dark blue), on a 10x10-km square basis.*

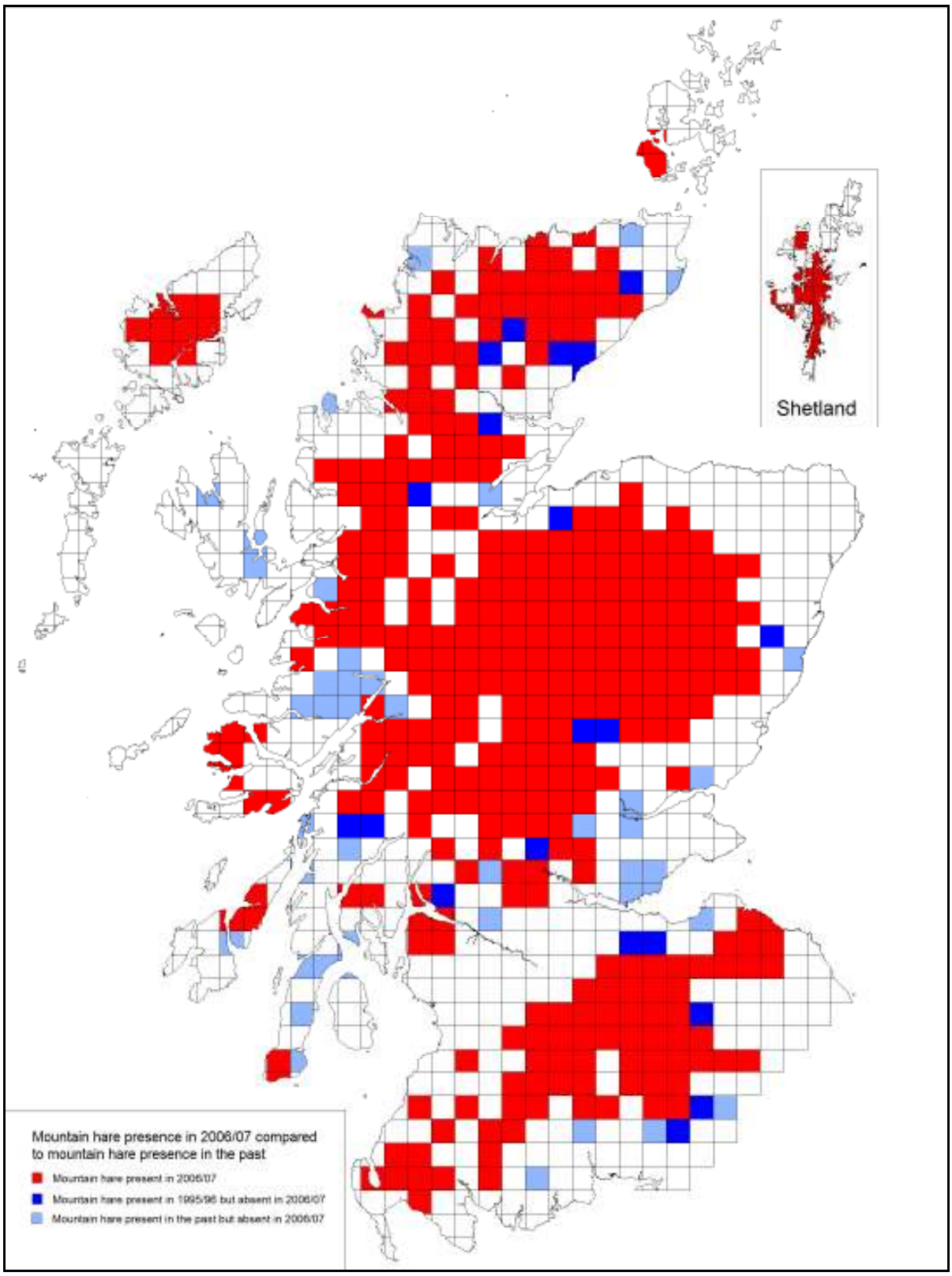
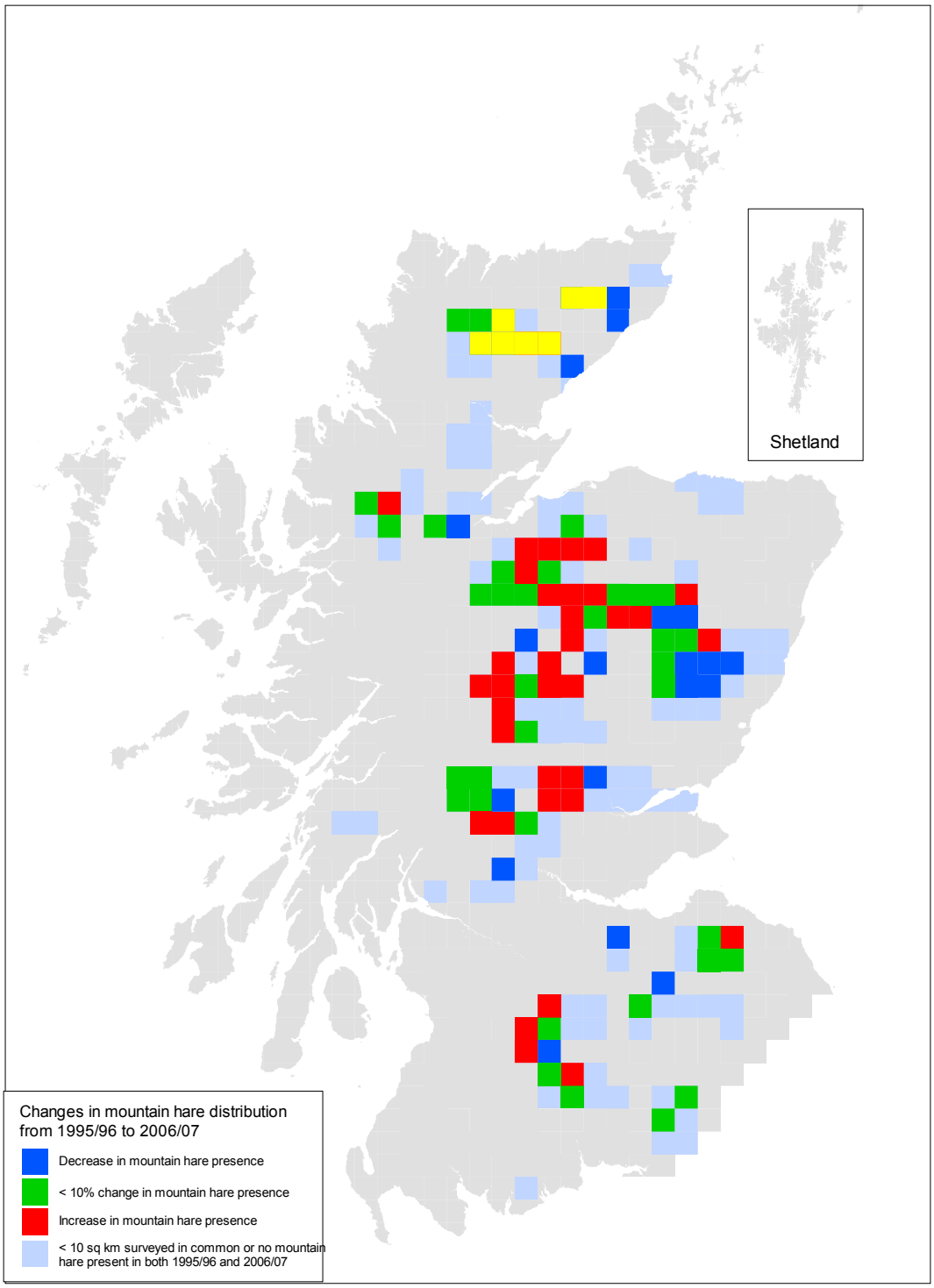


Figure 7 *Comparison between the distribution of mountain hares in Scotland in 1995/96 (Tapper 1996) and 2006/07, based upon the 1x1-km squares surveyed in both 1995/96 and 2006/07 (displayed here at the 10x10-km level).*



3.5 Mountain hare harvesting and population control

Of the 291 respondents who reported mountain hare presence, 104 (36%) harvested or controlled mountain hares to some extent in 2006/07, of which 90 estates provided details of the number of mountain hares taken. Of these 90 estates, 72% were driven grouse moors, with 7% walked-up grouse moors and 21% which had no grouse interest. A total of 68 driven grouse estates (24% of the total area of driven grouse moors in Scotland) did not return any mountain hare distribution or data on the level of take. Similarly, no data were received for 34 walked-up grouse moors (40% of the total area of walked-up moors).

The average mountain hare bag for each estate was calculated using the number of mountain hares taken on the estate divided by the total area of mountain hare presence (km^2) on the estate. Of those that provided seasonal information on the level of take (64 estates), the average mountain hare bag as well as the total numbers taken during the period March 2006 to February 2007 divided by season, method and reason are presented in Table 2. In addition, the total numbers taken on those estates that provided information on the level of take on an annual basis only (January 2006 to December 2006; 26 estates) are also presented in Table 2. The average mountain hare bag and the total taken by reason and method (seasonal and annual records combined) are shown in Table 3. The total mountain hares taken in 2006/07 by reason and method separately and the percentages of the total taken by reason, method and season can be found in Appendix 8. In addition, the number of hares taken per km^2 and the number of mountain hares taken by reason and region along with the percentages of the total taken in 2006/07 by reason and region are displayed in Appendix 8. Of all those taken, 40% of mountain hares (9,878) were taken for let/un-let shooting, 10% (2,392) were taken to protect forestry and 50% (12,259) taken for the purpose of tick control.

3.6 Mountain hare bag compared to the different estate types

In terms of the total bag for 2006/07, there were no differences between the mountain hare bag on either driven, walked-up or non grouse moor estates ($F_{2,87} = 2.21$, $P = 0.116$). Of the estates that harvested mountain hares through let/un-let shooting, there was no significant difference between the three estate types ($F_{2,55} = 1.08$, $P = 0.347$). The same was true for those that controlled mountain hare populations for forestry protection ($F_{2,30} = 2.59$, $P = 0.091$) or tick control ($F_{2,37} = 0.77$, $P = 0.468$).

Table 2 *Scottish mountain hares taken by reason, method and season given as mean number of hares taken per unit area (km^2) where they were found on an estate and total numbers taken. The number of estates who have contributed data is given in brackets. Please note that estates reported on the numbers of mountain hares taken either on a seasonal basis during the period March 2006 to February 2007 or on an annual basis from January 2006 to December 2006. The seasonal data do not thus sum to the annual, they represent the two ways that data were returned in this survey.*

Reason / Method		**Seasonal data**				**Annual data (Jan 06 - Dec 06)**
		Spring/ Summer 06 (Mar-Aug)	**Autumn 06 (Sept, Oct, Nov)**	**Winter 06/07 (Dec, Jan, Feb)**	**Total (Mar 06 - Feb 07)**	
Let/commercial/ formal shooting		2.1 591 (8)	3.9 1,494 (16)	5.7 3,504 (15)	7.2 5,589 (23)	6.1 939 (7)
Un-let/informal shooting		0.9 57 (4)	3.1 796 (17)	6.7 1,956 (13)	5.8 2,809 (25)	3.4 541 (11)
Forestry/ crop protection	Snare	1.1 149 (6)	0.8 106 (5)	1.7 384 (5)	2.4 639 (8)	1.7 110 (5)
	Shoot	1.1 297 (12)	1.9 343 (12)	1.4 471 (14)	2.8 1,111 (20)	5.2 532 (9)
Tick control	Snare	2.6 409 (5)	2.2 408 (6)	8.4 2,036 (8)	9.4 2,853 (10)	11.0 1,476 (3)
	Shoot	3.2 2,037 (17)	2.4 1,521 (19)	3.3 2,368 (22)	6.9 5,926 (25)	5.7 2,004 (11)
Total		**3.1** **3,540 (34)**	**4.1** **4,668 (49)**	**6.7** **10,719 (51)**	**10.2** **18,927 (64)**	**8.9** **5,602 (26)**

Table 3 Total number of mountain hares taken in Scotland from January 2006 to February 2007 (seasonal and annual returns combined) by reason and method, given as total / km^2 (percentage of the total number taken in brackets).

Reason / Method		**Mountain hares taken/km^2**
Let/commercial/formal shooting		11.2 6,528 (27%)
Un-let/informal shooting		9.7 3,350 (14%)
Forestry/crop protection	Snare	2.9 749 (3%)
	Shoot	5.3 1,643 (7%)
Tick control	Snare	18.0 4,329 (18%)
	Shoot	13.3 7,930 (32%)
Total		**10.7** **24,529***

3.7 Comparison with the level of take reported in 1995/96 (Tapper 1996)

The total number of mountain hares taken as reported in this survey cannot be compared directly to the numbers taken as reported by Tapper (1996) owing to the different numbers of respondents in the two surveys. Comparisons of the numbers taken were therefore made between those estates which were surveyed in both 1995/96 and 2006/07. The overall number of estates surveyed in 1995/96 and 2006/07 differed due to instances in which one estate in 1995/96 was managed as two estates in 2006/07 and vice versa. In these cases, the number of mountain hares taken on each of the two estates was combined to enable true comparisons for each estate. A total of 50 estates replied to both surveys, of which 56% (28 estates) harvested or controlled mountain hares in 1995/96 compared to 52% (26 estates) in 2006/07. There was a 32% increase in the number of mountain hares taken in 2006/07 compared to 1995/96. Of those estates which harvested/controlled mountain hares in 2006/07, 8,617 were taken by 20 estates in 1995/95, with a further 380 mountain hares taken across 8 estates. Of the estates which harvested/controlled in 1995/96, 10,519 mountain hares were taken by 20 estates in 2006/07 with a further 1,387 taken in 2006/07 across 6 estates (Tables 4a and 4b).

Table 4 *Comparison of the number of mountain hares taken between the 50 estates which were surveyed in common in 1995/96 and 2006/07. (a) The number of mountain hares taken in 1995/96 split by those estates which had taken in 2006/07 with the number of estates (from 1995/96) in brackets. (b) The number of mountain hares taken in 2006/07 split by those estates which had taken hares in 1995/96 with the number of estates (2006/07) in brackets.*

(a)

	1995/96	
	No mountain hares taken	Mountain hares taken
No mountain hares taken in 2006/07	0 (16)	380 (8)
Mountain hares taken in 2006/07	0 (6)	8,617 (20)
Total	**0 (22)**	**8,997 (28)**

(b)

	2006/07	
	No mountain hares taken	Mountain hares taken
No mountain hares taken in 1995/96	0 (16)	1,387 (6)
Mountain hares taken in 1995/96	0 (8)	10,519 (20)
Total	**0 (24)**	**11,906 (26)**

There were 26 estates which harvested or controlled mountain hares in 1995/96 that could not be matched with a returned questionnaire in this survey; a total of 7,344 mountain hares were taken across these estates. In contrast, 64 estates which harvested or controlled mountain hares in 2006/07 did not match a return from 1995/96 with a total of 12,623 mountain hares taken.

3.8 Level of take and changes in mountain hare distribution on an estate basis

Two measures of the level of take were used to compare with the changes in mountain hare distribution within estates between 1995/96 and 2006/07:

1. NGC returns from 1996 to 2006 (measured as the average yearly mountain hare bag per moorland area (km^2) of an estate).

2. The number of mountain hares taken as reported in this survey.

Only those estates for which mountain hare data were received from both the 1995/96 and 2006/07 surveys were used in the analysis.

As an alpha level of $P < 0.005$ was used to determine statistical significance, no significant correlation were found between the total mountain hare bag reported in this survey and the decline in mountain hares from 1995/96 to 2006/07 (Table 5).

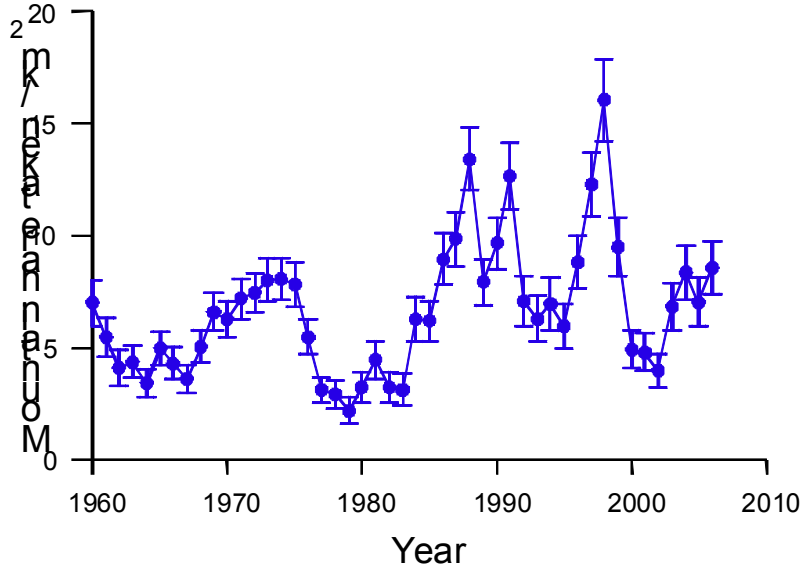
Table 5 Comparisons (correlation analysis) between changes in mountain hare distribution in Scotland (at the estate level) and the level of take, measured both through this survey for the year 2006/07 and through the NGC for the period 1996-2006.

Comparisons at the estate level		
Measure of the level of take	**Estates with increased distribution**	**Estates with decreased distribution**
Average bag from 1996-2006, NGC data	$r_{36} = +0.055$, $P = 0.742$	$r_{13} = +0.211$, $P = 0.451$
Total number taken, 2006/07 survey	$r_{66} = +0.138$, $P = 0.263$	$r_{40} = +0.254$, $P = 0.104$
Total taken for let/un-let shooting, 2006/07 survey	$r_{66} = +0.070$, $P = 0.571$	$r_{40} = +0.301$, $P = 0.052$
Total taken for forestry/crop protection, 2006/07 survey	$r_{66} = +0.007$, $P = 0.954$	$r_{40} = +0.270$, $P = 0.084$
Total taken for tick control, 2006/07 survey	$r_{66} = +0.045$, $P = 0.717$	$r_{40} = +0.027$, $P = 0.867$

3.9 National Gamebag Census: trends in the level of take of mountain hares

Mountain hare bag data were extracted from the National Gamebag Census for those estates within Scotland which had taken mountain hares between 1960 and 2006. The overall changes in the mountain hare bag across Scotland during this time period are of a cyclic nature (Figure 8. See also an extract from a report to JNCC by Davey & Aebischer (2008) in Appendix 9). It should be noted that other estates may have taken mountain hares during this timeframe but may not have submitted their figures to the NGC. The indices in Figure 8 are based on data from 185 estates, with a total of 2,642 bag returns.

Figure 8 Changes in the mountain hare bag since 1960. These indices are predictions (± standard errors) from a generalized linear model analysis (with Poisson error and logarithmic link function) controlling for variation between estates. Mountain hare bag is defined as the number of mountain hares taken divided by the area of moorland (km^2) within an estate. Data obtained from the National Gamebag Census.



4 DISCUSSION

This project was stimulated by the need for: (a) an assessment of mountain hare distribution in Scotland to use as a baseline for future robust analysis of population change; (b) an assessment of changes in mountain hare numbers and distribution in Scotland to the extent that is possible given the paucity of historical data; and (c) an investigation of the effect of historic and contemporary Scottish upland land management on mountain hares. The need for this research was highlighted by the adoption of the mountain hare as a UK Biodiversity Action Plan (BAP) species in July 2007.

4.1 Study design

A questionnaire survey was considered to be the most appropriate method as it meant that comparisons could be drawn with the previous survey of mountain hares (Tapper 1996) which had also been questionnaire-based. This questionnaire-based methodology also allowed an assessment of the level of human impact on mountain hare distributions through harvesting and control. The survey could not be used to assess the nature and drivers of population change because: i) it was not possible to assess the densities of mountain hares and relate these to the numbers taken for harvesting or population control; ii) the survey relied upon unverifiable data including the ability of the observers to correctly identify the species, its location and the numbers of any mountain hares taken; iii) there was no guarantee that estates surveyed in 1995/96 would return questionnaires in 2006/07. The methodology did however permit an assessment of the spatial distribution of mountain hares and the spatial and temporal distribution of the level of take and its underlying reasons.

4.2 Current distribution of mountain hares

This survey increased the size of the area assessed from 20,936km^2 in the 1995/96 JNCC survey (Tapper 1996) to 70,699 km^2 at the 10x10-km level. It confirms that, in Scotland, mountain hares are widespread in upland areas and are strongly associated with areas of heather moorland managed for grouse production (Hudson 1992). It is likely that habitat management and predator control for red grouse are likely to benefit both mountain hares and grouse (Hewson 1984), although the role of predators or habitat management on mountain hare population dynamics have not been empirically tested (Newey *et al.* 2007b). This study also confirms that mountain hares can occupy a wide range of habitats and can be found at low densities on grassland, unmanaged heather, woodland and commercial forestry plantation (Watson *et al.* 1973; Watson & Hewson 1973).

The 10x10-km squares with widespread consistent distribution were found to relate closely to those areas with high questionnaire return rates. It is possible that areas with lower questionnaire return rates may have hares present but the land occupiers are less interested in the species or that mountain hares are irregularly seen in these areas. These marginal areas are of potentially high importance to the Scottish mountain hare population as pressures from habitat loss and subsequent fragmentation effects may be greatest in these areas and could lead to population isolation and range contraction (Harris *et al.* 1995).

4.3 Change in the distribution of mountain hares

With the exception of Tapper (1996), the lack of geographically referenced quantitative data on current or historic mountain hare distribution makes it difficult to conduct any meaningful assessment of changes in distribution. Comparisons of the area surveyed in Tapper's (1996) study and the current study (on a 10x10-km square basis) suggest that there has been no real net gain or loss in distribution, although it is not possible to assess whether mountain hare distribution has changed outwith this area. In addition, it is not possible to comment on whether there have been any changes in mountain hare abundance during this time. A total of 65 respondents reported that mountain hares were no longer present in areas where they had been present in the past; however, the nature of the survey data makes it difficult to quantify these reports, or assess the underlying reasons, without undertaking follow-up work. It appears that the most dynamic areas of distribution change since 1995/96, where mountain hares have either appeared or disappeared, are at the margins rather than within the core area of the distribution. Some of the areas in which mountain hares are no longer present are remote from the areas of core distribution and so recolonisation may be less likely.

4.4 Distribution and harvesting

There was no significant association found between the number of mountain hares taken in 2006/07 and the observed changes in distribution. A more comprehensive analysis of the National Gamebag Census data using the average number taken per area of moorland showed no relationship between the level of take over the last 11 years and changes in mountain hare distribution.

The number of hares reported taken, for 2006/07, in this report is 24,529. To try to put this level of take into some sort of context, Harris *et al.* (1995) estimated the UK mountain hare population to be 350,000 (±50%). Based on this figure the number of hares taken in 2006/07 corresponds to 7% of the 1995 population estimate. These figures however need to be treated with caution. The 350,000 is a pre-breeding estimate, while the bag records include

both pre- and post-breeding time periods. While the UK population estimate of 350,000 is the best estimate available Harris *et al.* (1995) cautioned that it could be up to either a 50% overestimate or underestimate. Mountain hare populations show large annual changes in abundance with 50% of game bag records showing high amplitude cyclic dynamics; population density can change more than 10 fold over the cause of a cycle (Davey & Aebischer 2008; Newey *et al.* 2007). Comparing the level of take in 2006/07 to a 1995 population estimate assumes that the UK population has not changed appreciably over the proceeding 10 years which represents an assumption we are unable to verify.

4.5 Harvesting and population control of mountain hares

Mountain hares have been harvested through organised and informal shooting for at least 150 years and in some areas remain an important quarry species (Tapper 1992; Tapper 1999). They are also taken to control numbers on grouse moors, to protect forestry plantations, woodland regeneration, and crops and in some cases, as bait for traps (Tapper, 1996; Hewson 1984). Compared to the 1995/96 survey there appear to have been major changes in the management of mountain hares. On those estates which reported mountain hares were taken in both surveys, the total number of mountain hares taken was 32% higher in 2006/07 than in 1995/96. Additionally, whereas in 1995/96 at least 60% of mountain hares taken were through let/un-let shooting, in 2006/07 only 40% were taken for this reason, with the majority (50%) taken for the express purpose of tick control and 10% taken for forestry or crop protection. The results indicate that 40 estates (44% of those that provided detailed data on the level of take) now manage their mountain hare populations at least partly for tick control. Both snaring and shooting are used to control hare numbers for tick control and forestry/crop protection. This study found that in 2006/07, 35% of mountain hares taken for management purposes were snared rather than shot, highlighting the fact that managers feel snaring is an important tool.

Mountain hares can be an important host for ticks and are also important for the transmission of the louping-ill virus. This study could not assess how effective the reported level of take has been in reducing hare densities, nor louping-ill prevalence, nor any impacts on grouse populations. However, results show that at this stage and at the scale of measurement of this survey (estate and 10x10-km square) that mountain hares are still present in the areas where population reduction for tick control has been implemented.

5 CONCLUSION

This project provides the most comprehensive survey of the distribution and management of mountain hares in Scotland. Although comparisons with an earlier survey using similar methods (Tapper 1996) have shown that there have been some local changes in distribution, there does not appear to have been any significant net loss or gain in mountain hare distribution in the last 11 years in the area surveyed in both 1995/96 and 2006/07. It is important to stress however, that it is not possible to comment on whether there have been any changes in distribution in the areas outwith those surveyed in both 1995/96 and 2006/07. Similarly, no conclusions can be drawn as to possible changes in the abundance of mountain hares as this survey provides information on distribution only. This survey could not provide data on the impact of mountain hare population reduction to control ticks and louping-ill on mountain hare densities. There was no relationship between the numbers of mountain hares taken in 2006/07 or over the past 11 years and the changes in distribution in the last 11 years.

Scottish mountain hares dwell in a mainly upland landscape, roughly 50% of populations show high-amplitude fluctuations or cycles, may have a limited dispersal capacity, and are strongly associated with heather moorland managed for red grouse shooting. The mountain hare is an iconic upland species and our only native lagomorph. It remains an important quarry species, but in certain circumstances it also plays a role in the spread and persistence of louping-ill for which its numbers are reduced as part of tick control measures. This complex set of conditions means that the long-term status of mountain hares, red grouse and heather moorland demands a thorough understanding of the species and how the species interact and respond to different management regimes. Whilst this report and the preceding report by Newey *et al*. (in press) are important first steps, there is need for research into the following areas:

- Monitor the long-term changes in distribution relative to this survey on a regular basis.
- Instigate measures of abundance throughout the range of mountain hares, as identified here, in order to assess the abundance of the Scottish mountain hare population.
- Investigate spatial pattern of change in abundance to determine if there is evidence for declines at the edges of the range and increases in the core. Explore how management, habitat and dispersal fit into this pattern?
- Combine population monitoring with measures of mountain hare bags to further investigate the relationship between moorland management, the level of take and changes in mountain hare abundance.

- Investigate whether mountain hare populations respond behaviourally to different levels of take and moorland management?
- Examine dispersal and meta-population dynamics of mountain hare populations in relation to habitat fragmentation and in the core and peripheral areas of their distribution.
- Examine the demography and population ecology of mountain hare populations outside the main grouse moor regions of Scotland.
- Determine the consequences and efficacy of controlling mountain hare numbers for the purpose of tick control in the presence of other hosts.

6 REFERENCES

Arnold, H.R. (1993) Atlas of mammals in Britain. London: HMSO. 144pp.

Cope, D.R., Iason, G.R. & Gordon, I.J. (2004) Disease reservoirs in complex systems: a comment on recent work by Laurenson *et al. Journal of Animal Ecology,* 73, 807–810.

Corbet, G.B. & Harris, S. (1991) The handbook of British mammals. Blackwell Scientific Publications, Oxford. 588pp.

Davey, P.A. & Aebischer, N.J. (2008) Participation of the National Gamebag Census in the mammal surveillance network. A report to JNCC for the year 2007/08.

Forestry Commission (2007) Forestry Facts & Figures 2007: A summary of statistics about woodland and forestry (www.forestry.gov.uk/statistics).

Gilbert, L., Norman, R., Laurenson, K., Reid, H., Hudson, P. (2001) Disease persistence and apparent competition in a three host community an empirical and analytical study of large scale, wild populations. *Journal of Animal Ecology,* 70, 1053-1061.

Harris, S., Morris, P., Wray, S. & Yalden, D. (1995) A review of British mammals: population estimates and conservation status of British mammals other than cetaceans. Joint Nature Conservation Committee, Peterborough. 176pp.

Hewson, R. (1970) Variation in reproduction and shooting bags of mountain hares in north-east Scotland. *Journal of Applied Ecology,* 7, 243-252.

Hewson, R. (1984) Mountain hare *Lepus timidus* bags and moor management. *Journal of Zoology,* 204, 563-565.

Hudson, P.J. (1992) Grouse in space and time: The population biology of a managed gamebird. Game Conservancy Ltd, Fordingbridge. 244pp.

Hudson, P.J., Dobson, A.P. & Newborn, D. (1998) Prevention of population cycles by parasite removal. *Science,* 282, 2256-2258.

Laurenson, M.K., Norman, R. A., Gilbert, L., Reid, H. W., & Hudson, P. J. (2003) Identifying disease reservoirs in complex systems: mountain hares as reservoirs of ticks and louping-ill virus, pathogens of red grouse. *Journal of Animal Ecology,* 72, 177-185.

Laurenson, M.K., Norman, R.A., Gilbert, L., Reid, H.W. & Hudson, P.J. (2004) Mountain hares, louping-ill, red grouse and harvesting: complex interactions but few data. *Journal of Animal Ecology,* 73 811–813.

McCullagh, P. & Nelder, J.A. (1996) Generalized linear models, 3rd edn. Chapman & Hall, London.

Macdonald, D.W., Mace, G.M. & Rushton, S. (1998) Proposals for future monitoring of British mammals. Department of the Environment, Transport and the Regions, London.

Newey, S., Iason, G. & Raynor, R. (in press) The conservation status and management of mountain hares. A report to SNH.

Newey, S., Willebrand, T., Haydon, D.T., Dahl, F., Aebischer, N.J., Smith, A.A., & Thirgood, S.J. (2007a) Do mountain hare populations cycle? *Oikos,* 116, 1547-1557.

Newey, S., Dahl, F., Willebrand, T., & Thirgood, S.J. (2007b) Unstable dynamics and population regulation in mountain hares: a review. *Biological Reviews*, 82, 527-549.

Newson, S. & Noble, D. (2005) The Production of population trends for UK mammals using BBS mammal data, 1995-2003. A report by the British Trust for Ornithology under contract to the Joint Nature Conservation Committee. 48pp.

Reynolds, J.C., O'Mahony, D. & Aebischer, N.J. (2006) Implications of 'cyclical' population dynamics for the conservation of Irish hares (*Lepus timidus hibernicus*). *Journal of Zoology* 270, 408–413.

Tapper, S. (1992) Game Heritage: An ecological review from shooting and gamekeeping records. Game Conservancy Ltd, Fordingbridge. 140pp.

Tapper, S. (1996) Distribution and level of take of native mountain hares *Lepus timidus*. A report by the Game Conservancy Trust under contract to the Joint Nature Conservation Committee. Contract: F76-01-23.

Tapper, S. (1999) A Question of Balance: Game animals and their role in the British countryside. Game Conservancy Ltd, Fordingbridge. 288pp.

The Wildlife Partnership (2005) Mountain hares in the Southern Uplands of Scotland - a report prepared by the Wildlife Partnership for the Southern Uplands Partnership.

Thompson, D.B.A., MacDonald, A.J., Marsden, J.H. & Galbraith, C.A. (1995) Upland heather moorland in Great Britain - A review of international importance, vegetation change and some objectives for nature conservation. *Biological Conservation,* 71, 163-178.

Thulin, C.G. (2003) The distribution of mountain hares *Lepus timidus* in Europe: a challenge from brown hares *L. europaeus*? *Mammal Review,* 33, 29-42.

Watson, A., Hewson, R., Jenkins, D. & Parr R. (1973) Population densities of mountain hares compared with red grouse on Scottish moors**.** *Oikos,* 24, 225-230.

Watson, A. & Hewson, R. (1973) Population densities of mountain hares (*Lepus timidus*) on western Scottish and Irish moors and Scottish hills. *Journal of Zoology,* 170, 159.

Wightman, A. (1996) Who owns Scotland. Canongate, Edinburgh. 238pp.

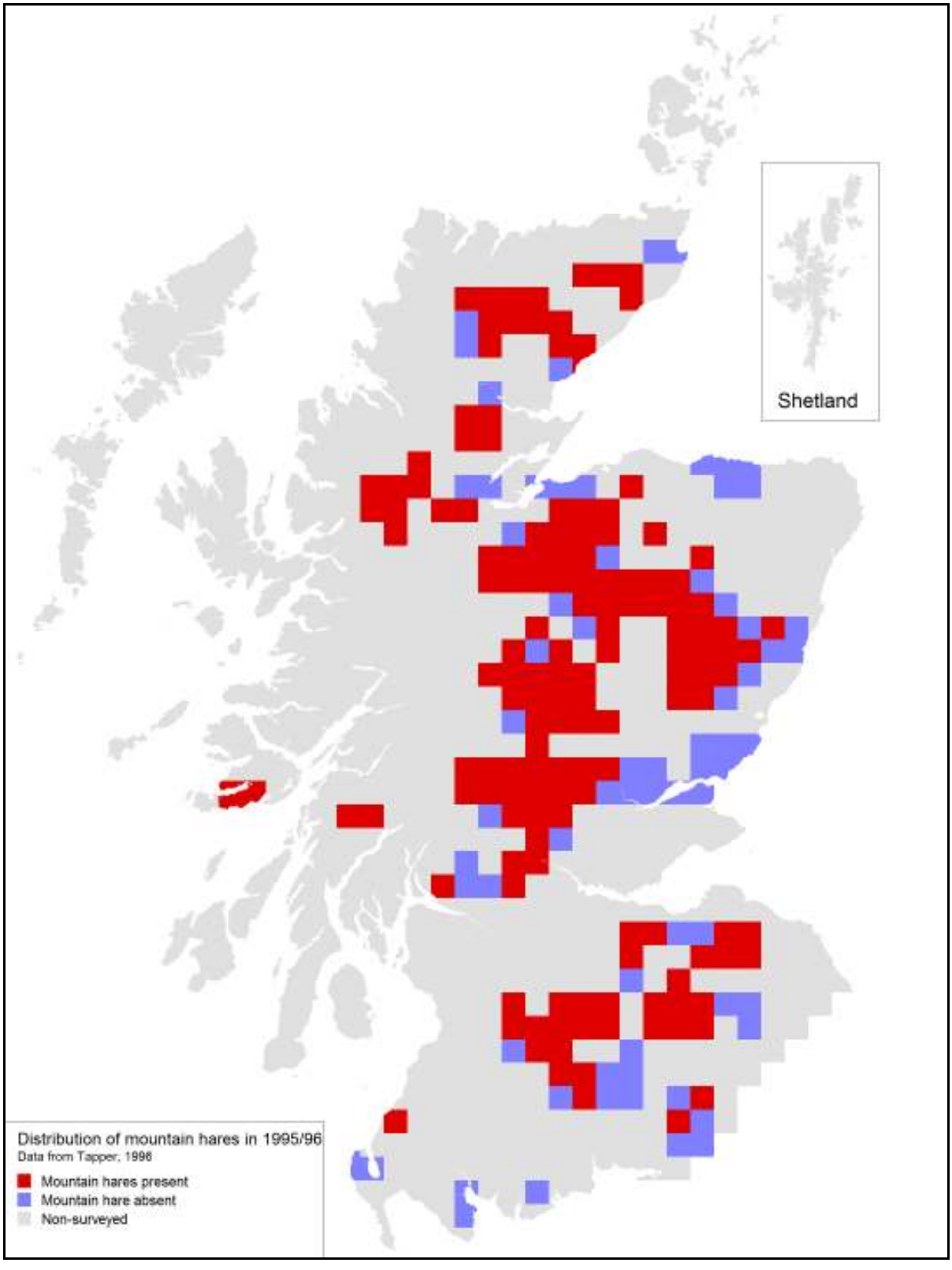
Wightman, A. & Boyd, G. (2001) Not-for-Profit landowning organisations in the highlands and islands of Scotland: sector review 2001.

Wightman A. (2001) Organisational Profiles: Not-for-Profit landowners in the highlands and islands of Scotland. Report prepared for Highlands and Islands Enterprise and Scottish Natural Heritage, Inverness.

Yalden, D. (1999) The history of British mammals. T & A D Poyster Ltd, London. 305pp.

Appendix 1

Distribution of mountain hares in 1995/96 as reported during the questionnaire survey performed by Tapper (1996).



Appendix 1 (continued)

Mountain hares taken in 1995/96 by region given as mean number of hares taken per area (km^2) where they were found on an estate and total numbers taken.

Region	**Harvest/control density and total taken per region**
Central Highlands	5.4 14,536
North West Highlands	9.0 116
Southern Uplands	0.1 1,689

Appendix 2

The survey questionnaire used by Tapper (1996) to obtain information on mountain hare distribution and the number of mountain hares taken by reason and season in 1995/96.

The Game Conservancy Trust
Scottish Mountain Hare Survey

Why a hare survey?

The Mountain Hare is an uncommon animal in many parts of Europe, and it is a species now listed in Annex V of the 1992 EC *Habitats Directive*. In Scotland it is still common but the numbers killed are often poorly recorded, and because Britain has an obligation to manage the exploitation this species under the *Habitats Directive*, the Joint Nature Conservation Committee has commissioned The Game Conservancy to survey Scottish upland shooting estates to determine the distribution of Mountain Hares in Scotland, and the current size of the bag from all sources.

What do I need to do?

As a moorland gamekeeper you are probably solely responsible for an upland beat which you know better and more intimately than anyone else. We would like you to use your knowledge to tell us first, approximately how many Mountain Hares were taken on your beat over the last twelve months (question 1), and second where on your beat Mountain Hares occur (question 2).

What's in it for me?

Everyone gets tired of filling in forms - so as a small incentive all forms completed and returned to us **by February 1st 1996 will become raffle tickets for a £100 prize**. Given the limited numbers of moorland keepers in Scotland the odds on winning are quite good.

All people sending us information and a completed questionnaire will also get a copy of the survey report when it is completed next spring.

Confidentiality.

Please note that all personal data from this survey will remain confidential and be retained by The Game Conservancy. Names and addresses and details of individual estates will under no circumstances be passed on to anyone else. The Joint Nature Conservation Committee will receive the hare distribution data, and the analysis of the results which will include trends in the bag and estimates of the annual cull. The biological information may be put on a computer database and used for conservation purposes.

Question 1

Approximately how many Mountain Hares were killed on your beat over the last twelve months?..... Please try to allocate this bag roughly by season and method, and put approximate numbers in the boxes below for 1994/5. Exclude natural losses, and road mortality etc.

	Winter 1994/95 Dec, Jan, Feb	**Spring 1995** Mar, Apr, May	**Summer 1995** Jun, Jul, Aug	**Autumn 1995** Sep, Oct, Nov
Organised shooting days.				
Shooting, trapping or snaring by gamekeeper.				
Shooting, trapping or snaring by others e.g. tenants.				
Other means.				

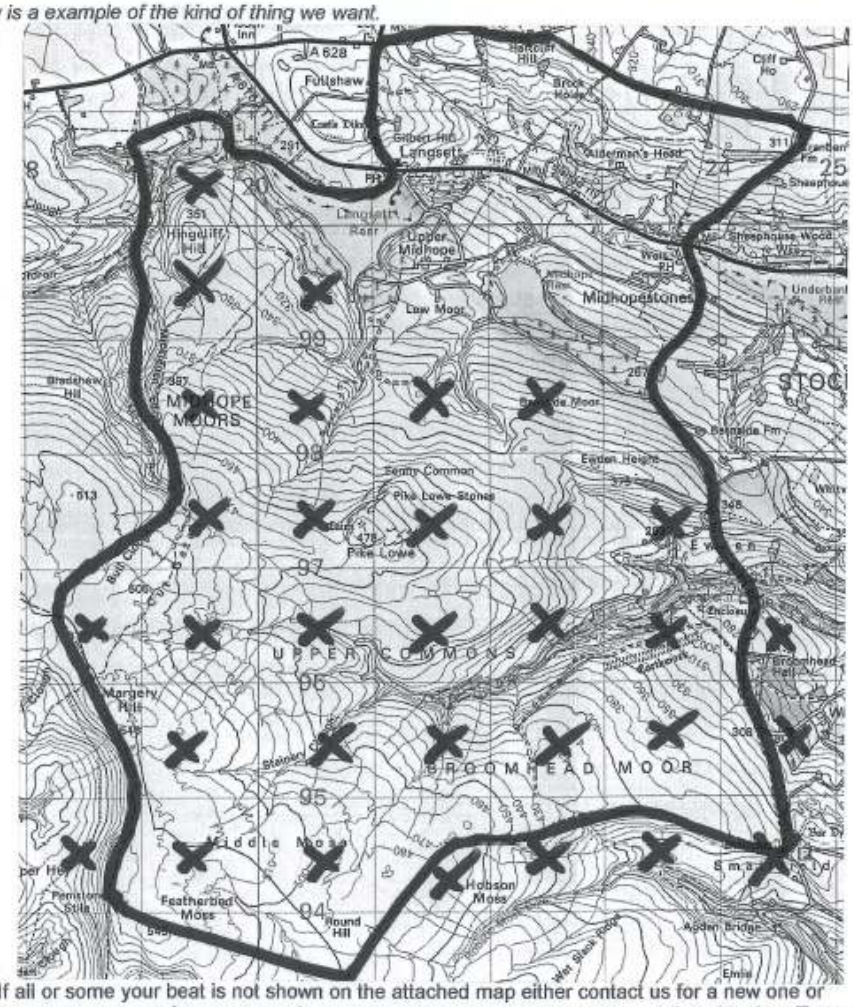
P.T.O.

Appendix 2 (continued)

Question 2

Where are Mountain Hares normally found on your beat ? On the large map attached, which should include your beat, please (1) draw a line around the perimeter of your beat and (2) mark with a cross those one kilometre squares in which you normally find Mountain Hares

Below is a example of the kind of thing we want.



..... If all or some your beat is not shown on the attached map either contact us for a new one or photocopy or trace one of your own and attach it to the form. *(Any problems... talk to Stephen Tapper or Michele Trebilco at The Game Conservancy .. Tel 01425-652-381)*

Gamekeeper's Details

Estate or Shoot .....

Name .....

Address .....

.....

.....Tel .....

Appendix 3i

Questionnaire mailed to estate contacts during this survey to obtain information on mountain hare distribution and the number of mountain hares taken by reason, method and season in 2006/07.

Hare today, where tomorrow?

Scottish Mountain Hare Survey

Complete the survey by 3 August 2007 -

Have a chance to win an original watercolour study of a Blue/Mountain Hare by well known wildlife artist Ashley Boon.

Why a hare survey?

Mountain hare numbers in Scotland are currently unknown. However under the EU Habitats Directive; the UK Government has an obligation to ensure the sustainable management of this species. It is important that decisions concerning future management of mountain hares are based on sound science. To make this possible, we need accurate information on the distribution of mountain hares, how they are managed and why.

Why is The Game Conservancy Trust involved?

The Trust uses science to promote game and wildlife management as an essential part of nature conservation. We are working in collaboration with SGA, The Macaulay Institute and SNH to provide the Scottish Executive with the most up to date science to inform this important issue.

We would like you to:

1. State where on your ground mountain hares occur;
2. Estimate how many mountain hares were taken on your ground over the last twelve months and indicate the main reason(s) why they are managed.

Please remember if you don't have hares on your ground, we still want to hear from you!

Confidentiality

All data submitted on the survey forms and maps will remain strictly confidential and will be seen only by The Game Conservancy Trust staff. Only data summaries will be passed on to third parties, and solely for the purpose of this project. For example, the hare distribution data will be grouped at the 10 by 10 km square level before being shared with Scottish Natural Heritage and the Macaulay Institute, the GCT's project partners; example overleaf.

At the end of the survey, all people returning complete forms will receive a newsletter summarising the results. As an incentive to fill out this form and return it to us, forms returned by 3 August 2007 will be entered into a raffle to win either an original watercolour study of a Blue/Mountain Hare by Wildlife & Sporting Artist, Ashley Boon (www.ashleyboon.co.uk) or two bottles of 10 year old Famous Grouse Malt, kindly provided by Edrington Group, owners of The Famous Grouse. The draw will take place by the end of August, judge's decisions are final and the winner will be notified by post. No correspondence will be entered into.

Appendix 3i (continued)

Question 1

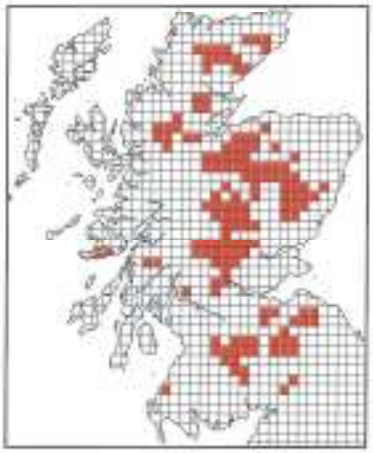
Where do mountain hares currently (since spring 2006) occur on your ground?

On the enclosed copy of the Ordnance Survey 1:50,000 map centred around your home address please:

1. Draw a line around the perimeter of your ground.
2. Mark with a cross the 1-km squares where you normally find mountain hares.

Below is an example of what we are asking for.

Example of final product map for publication.



If all or some of your ground is not shown on the attached map, either contact us for a new one (Julie Ewald at 01425 652 381), photocopy / trace one of your own and attach it to the form or try www.ordnancesurvey.co.uk/oswebsite/getamap.

Question 2

Approximately how many mountain hares were killed on your ground over the last twelve months?

Please **approximate bag numbers per season, method and reason** in the boxes below (excluding natural losses and road mortality). If you do not have access to figures for each season, please fill in the final, *i.e.* annual column.

Reason		Spring/Summer 2006 Mar. through Aug.	Autumn 2006 Sept, Oct, Nov	Winter 2006/2007 Dec, Jan, Feb	Annual - 2006 Jan 2006 – Dec 2006
Let/commercial/formal shooting					
Un-let/informal shooting*					
Reason	**Method****	Spring/Summer 2006 Mar. through Aug.	Autumn 2006 Sept, Oct, Nov	Winter 2006/2007 Dec, Jan, Feb	Annual - 2006 Jan 2006 – Dec 2006
Forestry/Crop protection	Snare				
	Shoot				
Tick Control	Snare				
	Shoot				

*Taken during other sporting activities etc. ** It is important to demonstrate the value of snaring for these purposes, so if you have the information available please provide it. Otherwise, indicate that you do not have it and please provide general numbers culled for this purpose.

Any comments concerning management of mountain hare (include information on natural die-offs, other methods).

If there are any problems please contact Adam Smith at The Game Conservancy Trust, Drumochter (01528 522300) or Julie Ewald at The Game Conservancy Trust, Fordingbridge (01425 652381).

Return this form and the attached map (or similar) in the return envelope provided.

Appendix 3ii

Questionnaire mailed to organisational contacts during this survey to obtain information on mountain hare distribution and the number of mountain hares taken by reason, method and season in 2006/07.

Hare today, where tomorrow?

Why a Mountain Hare survey?

Under the EU Habitats Directive the UK Government has an obligation to ensure the sustainable management of Mountain Hares. At present Mountain Hare numbers and their distribution within Scotland are unknown. In order to allow for informed decisions on the future management of the species it is therefore necessary to obtain accurate information on their current distribution, how they are managed and why. At the request of Scottish Natural Heritage, The Game Conservancy Trust has agreed to coordinate this survey of Mountain Hares within Scotland. The Game Conservancy Trust uses science to promote game and wildlife management as an essential part of nature conservation and is therefore well placed to perform this work. The GCT are working in collaboration with SNH, The Scottish Gamekeepers Association and The Macaulay Institute and the results of the survey will provide the Scottish Executive with the most up to date science to inform on this important issue.

Why have I been contacted?

We have already contacted over 3000 members from both the GCT and SGA asking for help with the survey and have received a good response to date. However, there are areas of Scotland not managed by our members and therefore we would like to ask for your help to achieve as complete an understanding as possible of Scottish Mountain Hare distribution.
If possible, we would like you to:

1. Outline your boundary on the map provided - whether you have Mountain Hares present or not;
2. If Mountain Hares do occur on your ground indicate where you have seen them since Spring 2006;
3. Estimate how many Mountain Hares were taken on your ground over the last twelve months and indicate the main reason(s) why they are managed.

Please remember if you don't have hares on your ground, we still need to hear from you.

Confidentiality

All data submitted on the survey forms and maps will remain strictly confidential and will be seen only by The Game Conservancy Trust staff. Only data summaries will be passed on to third parties, and solely for the purpose of this project. For example, the Mountain Hare distribution data will be grouped at the 10 by 10 km square level before being shared with Scottish Natural Heritage and the Macaulay Institute, the GCT's project partners (see example overleaf).

At the end of the survey, all people returning completed forms will receive a newsletter summarising the results. As an incentive to fill out this form and return it to us, **forms returned by 31st August 2007 will be entered into a raffle** to win either an original watercolour study of a Blue/Mountain Hare by Wildlife & Sporting Artist, Ashley Boon or two bottles of 10 year old Famous Grouse Malt kindly provided by Edrington Group, owners of The Famous Grouse. The draw will take place by the end of September, judge's decisions are final and the winner will be notified by post. No correspondence will be entered into.

Appendix 3ii (continued)

Question 1

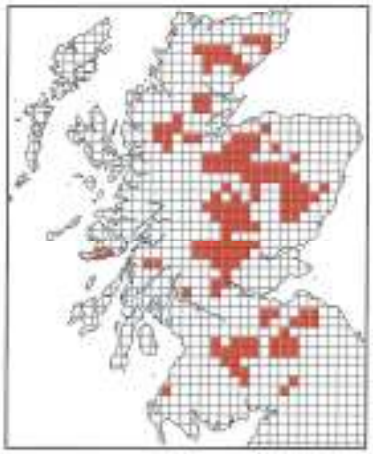
Where do mountain hares currently (since spring 2006) occur on your ground?

On the enclosed copy of the Ordnance Survey 1:50,000 map centred around your home address please:

1. Draw a line around the perimeter of your ground.
2. Mark with a cross the 1-km squares where you normally find mountain hares.

Below is an example of what we are asking for.

Example of final product map for publication.



If all or some of your ground is not shown on the attached map, either contact us for a new one (Julie Ewald at 01425 652 381), photocopy / trace one of your own and attach it to the form or try www.ordnancesurvey.co.uk/oswebsite/getamap.

Question 2

Approximately how many mountain hares were killed on your ground over the last twelve months?

Please **approximate bag numbers per season, method and reason** in the boxes below (excluding natural losses and road mortality). If you do not have access to figures for each season, please fill in the final, *i.e.* annual column.

Reason		Spring/Summer 2006 Mar. through Aug.	Autumn 2006 Sept, Oct, Nov	Winter 2006/2007 Dec, Jan, Feb	Annual - 2006 Jan 2006 – Dec 2006
Let/commercial/formal shooting					
Un-let/informal shooting*					
Reason	**Method****	Spring/Summer 2006 Mar. through Aug.	Autumn 2006 Sept, Oct, Nov	Winter 2006/2007 Dec, Jan, Feb	Annual - 2006 Jan 2006 – Dec 2006
Forestry/Crop protection	Snare				
	Shoot				
Tick Control	Snare				
	Shoot				

*Taken during other sporting activities etc. ** It is important to demonstrate the value of snaring for these purposes, so if you have the information available please provide it. Otherwise, indicate that you do not have it and please provide general numbers culled for this purpose.

Any comments concerning management of mountain hare (include information on natural die-offs, other methods).

If there are any problems please contact Adam Smith at The Game Conservancy Trust, Drumochter (01528 522300) or Julie Ewald at The Game Conservancy Trust, Fordingbridge (01425 652381).

Return this form and the attached map (or similar) in the return envelope provided.

Appendix 3iii

Questionnaire leaflet made available to members of the public to enable the recording of incidental mountain hare sightings during 2006/07 for this survey.

Hare today, where tomorrow?

Scottish Mountain Hare Survey

Complete the survey by 31 August 2007 -
Have a chance to win an original watercolour study of a Blue/Mountain Hare by well known wildlife artist Ashley Boon.

Why a hare survey?

Mountain hare numbers in Scotland are currently unknown. However under the EU Habitats Directive; the UK Government has an obligation to ensure the sustainable management of this species. It is important that decisions concerning future management of mountain hares are based on sound science. To make this possible, we need accurate information on the distribution of mountain hares. Visitors to the Scottish uplands are uniquely placed to provide valuable information on sightings of mountain hare.

What can you do?

We would like you to:

- Record a four figure grid reference of where you have seen mountain hare since March 2006, together with the name of a village or landscape feature nearby.
- Email or post us the grid reference and local landscape feature to the address below, together with your name and address if you wish to be entered into the raffle and receive a copy of the newsletter summarising the results.

Identifying mountain hare

The mountain hare is sometimes known as the blue hare because of its blue-grey summer coat (the period when this survey is being undertaken), in contrast to the rich-brown fur of the brown hare. The mountain hare's winter coat is white, while the brown hare's coat remains brown. The mountain hare is also smaller than the brown hare, having a body length of around 50-60 cm, with a more rounded shape, and without a black upper surface on the tail. Mountain hares also have shorter ears and legs than the brown hare, although both types of hare have much longer ears and hind legs than rabbits which are sometimes confused with hares. Rabbits are smaller, and do not have black tips to the ears.

What's in it for me?

At the end of the survey, all people returning complete forms will receive a newsletter summarising the results. As an incentive to fill out this form and return it to us, forms returned by 31 August 2007 will be entered into a raffle to win either an original watercolour study of a Blue/Mountain Hare by Wildlife & Sporting Artist, Ashley Boon (www.ashleyboon.co.uk) or two bottles of 10 year old Famous Grouse Malt, kindly provided by Edrington Group, owners of The Famous Grouse.
The draw will take place by the end of September, judge's decisions are final and the winner will be notified by post. No correspondence will be entered into.

Confidentiality

Please note that all data submitted will remain strictly confidential. Only data summaries will be passed on to third parties, and solely for the purpose of this project. For example, the hare distribution data will be grouped at the 10 by 10 km square level before being shared with Scottish Natural Heritage and the Macaulay Institute, the GCT's partners in this project.

Please send details of mountain hares to: smh@gct.org.uk

Or by post to:
The Scottish Mountain Hare Survey
The Game Conservancy Trust
Fordingbridge
SP6 1EF

For information specifically regarding Mountain hares, their status in Scotland etc. contact Adam Smith at The Game Conservancy Trust, Drumochter (01528 522 300)
For more information regarding this survey please phone: 01425 652 381 and ask for The Scottish Mountain Hare Survey Team.

Further copies of this questionnaire can be downloaded from the Game Conservancy Trust's Scottish Mountain Hare survey

Appendix 4

The Not-for-Profit organisations and governmental bodies contacted during this survey to obtain information on mountain hare distribution and the number of mountain hares taken by reason, method and season in 2006/07 on their land. The total area of land they each own within Scotland is detailed.

Not-for-Profit organisations

NfP Organisation	**Area Owned (hectares)**
National Trust for Scotland	71,183
RSPB	38,986
Stornoway Trust	28,085
John Muir Trust	20,414
Scottish Wildlife Trust	9,517
Glendale Crofters Estate	9,307
Assynt Crofters' Trust	8,619
Clan Donald Lands Trust	8,093
Knoydart Foundation	6,960
Church of Scotland General Trustees	6,070
Hoy Trust	5,058
The Woodland Trust	5,058
Melness Crofters Estate	4,359
Isle of Eigg Heritage Trust	2,994
Borve & Annishader Township Ltd	1,859
Total area	**226,562**

Information obtained from Wightman & Boyd (2001)

Governmental bodies

Governmental body	**Area Owned (hectares)**
Forestry Commission	457,000
SGRPID (Scottish Government)	113,860
Scottish Natural Heritage	34,191
Defence Estates (MOD)	20,407
Total area	**625,458**

Information obtained from Wightman (1996) and Forestry Commission (2007)

Appendix 5

The conservation, wildlife and hill-walking organisations contacted within Scotland to advise them of the survey and to request that they inform members and employees of its details.

Association for the Protection of Rural Scotland
Badenoch and Strathspey Conservation Group
Buglife - The Invertebrate Conservation Trust
Cairngorms Campaign
Friends of Loch Lomond
Friends of The Earth Scotland
Hebridean Whale and Dolphin Trust
Marine Conservation Society
North East Mountain Trust
Plantlife Scotland
Ramblers' Association Scotland
Scotland Office of Butterfly Conservation
Scottish Agricultural College
Scottish Council for National Parks
Scottish Countryside Rangers Association
Scottish Crofter's Commission
Scottish Native Woods
Scottish Raptor Study Groups
Scottish Wild Land Group
Soil Association Scotland
Sustrans Scotland
The Bat Conservation Trust
The Council for Scottish Archaeology
The Mammal Society
The Mountaineering Council of Scotland
The Saltire Society
Tracking Mammals Partnership, JNCC
Whale and Dolphin Conservation Society
Wildfowl & Wetlands Trust
Woodland Trust Scotland
WWF Scotland

Appendix 6

Mountain hare poster used to inform visitors to Scotland of the survey which was sent to Scottish Tourist Information Centres for display within each office.

Help Survey Scotland's Mountain Hare

Why a hare survey?

Mountain hare numbers in Scotland are currently unknown; however, under the EU Habitats Directive the UK Government has an obligation to ensure the sustainable management of this species. It is important that decisions concerning future management of mountain hares are based on sound science. To make this possible, we need accurate information on the distribution of mountain hares. Visitors to the Scottish uplands are uniquely placed to provide valuable information on sightings of mountain hare.

What can you do?

We would like you to:

1. Record a four figure grid reference of where you have seen mountain hare from March 2006 together with the name of a village or landscape feature nearby.
2. Email or post the grid reference and local landscape feature to the address below. If you wish to receive a copy of The Game Conservancy Trust newsletter summarising the results of the survey please include your name and address.

Identifying mountain hare

The mountain hare is sometimes known as the blue hare because of its blue-grey summer coat in contrast to the rich-brown fur of the brown hare. The mountain hare is smaller than the brown hare with a body length of around 50-60 cm, a more rounded shape and without a black upper surface on the tail. Mountain hares also have shorter ears and legs than the brown hare, although both types of hare have much longer ears and hind legs than rabbits which are sometimes confused with hares. Rabbits are smaller and do not have black tips to the ears.

Confidentiality

Please note that all data submitted will remain strictly confidential. Only data summaries will be passed on to third parties and solely for the purpose of this project. For example, the hare distribution data will be grouped at the 10 by 10 km square level before being shared with Scottish Natural Heritage and the Macaulay Institute, the GCT's partners in this project.

Further Information

Please send your sightings to: smh@gct.org.uk
Or by post to: Scottish Mountain Hare Survey
The Game Conservancy Trust
Fordingbridge
SP6 1EF

Please send your mountain hare sightings by end September 2007 for inclusion in the survey

Further information and survey forms can be found on the website: www.gct.org.uk/smhs or by contacting The Game Conservancy Trust on 01425 652 381

Appendix 7

Articles presented by the press during this survey to further publicise the need for mountain hare sighting data from land owners, managers, gamekeepers and members of the public.

When	Media	Name
07/06/2007	Magazine	Shooting Times and Country
09/06/2007	Newspaper	Scottish Daily Mail
14/06/2007	Newspaper	Berwickshire News and East Lothian
14/06/2007	Newspaper	Southern Reporter
28/07/2007	Newspaper	The Press & Journal (Central)
28/07/2007	Newspaper	The Press & Journal (Aberdeen Edition)
August 2007	Magazine	Shooting & Conservation
August 2007	Magazine	Sporting Shooter
August 2007	Newspaper	The Field
02/09/2007	Newspaper	The Sunday Times Scotland
08/09/2007	Newspaper	The Herald (Glasgow)
27/10/2007	Radio	BBC Radio 4, Open Country

Appendix 8

Total mountain hares taken in 2006/07 by reason with the number of estates who have contributed data in brackets and as a percentage of the total annual figure for 2006/07.

Reason	Total taken 2006/07	Percentage of total taken
Let/un-let shooting	9,878 (59)	40.3%
Forestry/crop protection	2,392 (33)	9.7%
Tick control	12,259 (40)	50.0%

Total mountain hares taken in 2006/07 by method of control and as a percentage of the total annual figure for 2006/07.

Method	Reason	Total taken 2006/07	Percentage of total taken
Shot	Let/un-let shooting	9,878	40.3%
	Forestry & tick	9,573	39.0%
Snared	Forestry & tick	5,078	20.7%

Mountain hares taken in 2006/07 by reason, method and season as a percentage of the total taken in 2006/07. Please note that estates reported on the number of mountain hares taken either on a seasonal basis during the period March 2006 to February 2007 or on an annual basis from January 2006 to December 2006.

Reason / Method		Seasonal data			Annual data (Jan 06 – Dec 06)
		Spring/Summer 06 (Mar - Aug)	Autumn 06 (Sept, Oct, Nov)	Winter 06/07 (Dec, Jan, Feb)	
Let/commercial/formal shooting		2.4%	6.1%	14.2%	3.8%
Un-let/informal shooting		0.2%	3.2%	8.0%	2.2%
Forestry/crop protection	Snare	0.6%	0.4%	1.6%	0.4%
	Shoot	1.2%	1.4%	1.9%	2.2%
Tick control	Snare	1.7%	1.7%	8.3%	6.0%
	Shoot	8.3%	6.2%	9.7%	8.2%
Percentage of total taken in 2006/07		**14.4%**	**19.0%**	**43.7%**	**22.8%**

Appendix 8 (continued)

Mountain hares taken in 2006/07 by reason and region given as number of hares taken per area (km^2) where they were found on an estate and total numbers taken. The number of estates who have contributed data is given in brackets.

	Region		
Reason	**Central Highlands**	**North West Highlands**	**Southern Uplands**
Let/un-let shooting	6.0 7,928 (46)	0.0 0 (0)	9.1 1,950 (13)
Forestry/crop protection	2.4 982 (17)	1.1 15 (3)	6.3 1,395 (14)
Tick control	9.2 11,759 (39)	0.0 0 (0)	6.3 500 (2)
Total per region	**9.9** **20,669 (67)**	**1.1** **15 (3)**	**10.9** **3,845 (20)**

Mountain hares taken in 2006/07 by reason and region as a percentage of the total taken in 2006/07.

	Region		
Reason	**Central Highlands**	**North West Highlands**	**Southern Uplands**
Let/un-let shooting	32.3%	0.0%	8.0%
Forestry/crop protection	4.0%	0.1%	5.7%
Tick control	47.9%	0.0%	2.0%
Percentage of total taken 2006/07	**84.2%**	**0.1%**	**15.7%**

Appendix 9

Extracted from Davey & Aebischer, 2008.

The National Gamebag Census

The NGC was formally established by the Trust in 1961, and is a voluntary scheme that currently collects bag statistics from over 600 shooting estates annually in England, Wales, Scotland and Northern Ireland. Through the inclusion of data from historical game books, series for several species extend back to the 19th century. The Trust believes that the NGC approach, which targets the estate rather than individual shooters, is the best way of assessing bags on driven shoots. The NGC statistics also include bags from rough shooting carried out on the same estates, and much of the mammal bag data held by the NGC is derived from this type of estate activity.

At the end of each shooting season, each participant completes an annual bag survey form detailing the numbers of each species shot, numbers released and numbers of shoot days, estate area and, in the case of upland estates, moorland area. In many cases, additional data extracted from game books extend the time series back to at least the 19th century. Reminders are issued for non-returned forms and the return rate exceeds 85%. The data are expressed as the numbers of animals shot per unit area, providing temporal and regional trends in bags on shooting estates (Tapper 1992; Aebischer & Baines, in press).

Percentage changes in bags for NGC mammals

For each species, analysis was based on all annual shoot returns greater than zero. Shoots contributing only one year's data were omitted. Statistical analysis followed the approach adopted by Whitlock, *et al.* (2003) and was carried out using GenStat (Lawes Agricultural Trust, Rothamsted). For each species, bag data were analysed using a generalised linear model (McCullagh & Nelder 1996) with a Poisson error distribution and logarithmic link function, with shoot and year as factors and the logarithm of shoot area as an offset variable. For mountain hare the bag data spanned the period from 1961 to 2006.

The year coefficients were exponentiated to give an index of bag size on the arithmetic scale. All index values were relative to the start year, which had a value of 1. The 95% confidence intervals around the index values were obtained by bootstrapping at the shoot level: for each of 199 bootstrap runs, shoots equal in number to the original sample were selected at random with replacement and a new set of indices obtained as described above. For each year, the 95% confidence limits were taken as the lower and upper 95th percentiles of the distribution of all 200 index values.

To measure the percentage change between specified start and end years, a generalized addition model (GAM, Hastie & Tibshirani 1990) was fitted to the full series of bag indices with one degree of freedom per decade or part-decade, then the percentage change calculated from the GAM fitted values for the start and end years. The 95% confidence limits were obtained by fitting GAMs to each bootstrap sample, calculating each percentage change, and selecting the lower and upper 95th percentiles of the 200 values that resulted. If the 95% confidence interval did not include zero, then the corresponding percentage change was declared significant at $P<0.05$.

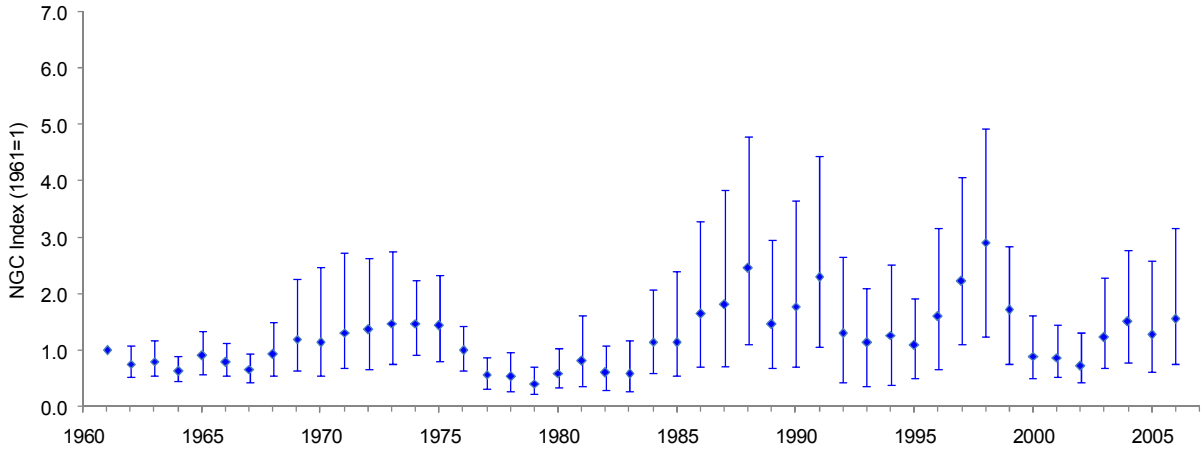
This procedure resulted in bag indices and confidence limits from the NGC data for the period 1961 to 2006. Bag indices were expressed relative to the first year of each series, so the index value for the first year of each series is always one.

Summary: A cyclic trend in the index of bag density in the UK between 1961 and 2006, with increases from 1967 to 1974, 1983 to 1988, and 1995 to 1998 alternating with poor seasons. Overall, there were no significant long-term trends.

a) Sample size and % change of Mountain Hare bags.

		1961-2006		1995-2006	
	Sample	**Change**	**95% CI**	**Change**	**95% CI**
Scotland	184	63.3	-16.7 to 250	-22.6	-58.5 to 58.2
ENVIRONMENTAL ZONES					
1. Lowlands	28	0.6	-78.7 to 375.0	60.8	-2.7 to 459.8
2. Intermediate uplands/islands	23	-36.2	-86.4 to 700.2	-12.6	-35.8 to 161.1
3. True uplands	133	80.7	-23.0 to 288.6	-28.3	-65.9 to 51.2

b) Change in relative bag density in Scotland from 1961 to 2006. Error bars represent 95% confidence intervals.



References for Appendix 9:

Aebischer, N.J. & Baines, D. in press. Monitoring gamebird abundance and productivity in the UK: the GCT long-term datasets. *Turk.J.Zool.*

Hastie, T.J. & Tibshirani, R.J. (1990) Generalized Additive Models. Chapman & Hall, London.

McCullagh, P. & Nelder, J.A. (1996) Generalized linear models, 3rd edn. Chapman & Hall, London.

Tapper, S. (1992) Game Heritage: An ecological review from shooting and gamekeeping records. Game Conservancy Ltd, Fordingbridge. 140pp.

Whitlock, R.E., Aebischer, N.J. & Reynolds, J.C. (2003) The National Gamebag Census as a tool for monitoring mammal abundance in the UK. GCT Research Report to JNCC. The Game Conservancy Trust, Fordingbridge.