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The status and distribution of summering Greylag Geese *Anser anser* in Scotland, 2008–09

CARL MITCHELL[1]*, LARRY GRIFFIN[2], MARK TRINDER[1,3], JULIA NEWTH[1] and CHRISTINE URQUHART[4]

[1]Wildfowl & Wetlands Trust, Slimbridge, Gloucester GL2 7BT, UK, [2]Wildfowl & Wetlands Trust, Eastpark Farm, Caerlaverock, Dumfriesshire, Scotland DG1 4RS, UK, [3]RPS, 7 Clairmont Gardens, Glasgow G3 7LW, UK and [4]Scottish Natural Heritage, 1 Kilmory Industrial Estate, Kilmory, Lochgilphead, Argyll PA31 8RR, UK

Capsule Summering Greylag Geese *Anser anser* are increasing in number and expanding their range in Scotland.

Aims During the summers of 2008 and 2009, extensive surveys of Greylag Geese in Scotland were undertaken to update the current distribution and population estimates, as well as estimate breeding success.

Methods Checks of known moult-sites were combined with a random stratified sample of lochs to the south and east of the Great Glen (the 're-established population' area). Sample lochs were selected on the basis of altitude, the proportional areas of woodland and water cover and previous summer records of Greylag Geese within the 10-km squares in which the lochs were located. To the north and west of the Great Glen (the 'northwest Scotland' population area), comprehensive post-breeding counts of feeding areas were undertaken in late August.

Results Combined results from 2008 and 2009 suggest an estimated 47 405 (range 44 059–51 763) Greylag Geese in Scotland. Since 1989, Greylag Geese encountered to the south and east of the Great Glen (derived from re-established birds) have increased at an annual rate of about 9.7% per annum and, since 1997, those in northwest Scotland have increased at an annual rate of about 11.7% per annum. It is estimated that the total number of Greylag Geese summering in Britain is about 84 500 birds. In 2008, overall breeding success was 24.1% young in the late summer population, which probably more than compensates for natural and shooting mortality.

Conclusion There is no indication of a decline in the rate of increase of Greylag Geese in Scotland and the species is expected to continue to increase in abundance and distribution.

Estimating the size of bird populations is a prerequisite for effective conservation and management of both harvested and endangered species. Assessing the current abundance and distribution of species, especially those that come into conflict with agricultural interests, is of particular importance to natural resource managers and those in government charged with establishing wildlife policies. Scotland is an important destination for migratory goose species including a significant proportion of the global populations of Barnacle Geese *Branta leucopsis*, Pink-footed Geese *Anser brachyrhynchus*, Greylag Geese A. *anser* breeding in Iceland, and Greenland White-fronted Geese A. *albifrons flavirostris*. Since the 1960s, the number of geese wintering in Scotland has increased because of changes in agricultural practices, legislative protection of some populations from hunting, and protection of important roosts. The increase in abundance has brought geese into conflict with farmers because the geese depend primarily on farmland for their food supply during the non-breeding season.

Greylag Geese are the only native goose species breeding in Britain and are largely sedentary (Swann & Brockway 2002). In the late 18th century they were much more widely distributed within Britain, breeding throughout Scotland and more locally in England, Wales and Ireland (Holloway 1996). During the 19th century numbers began to decline, becoming extinct in England, probably because of drainage and cultivation of the fens, and over-hunting. In Scotland, during the

*Correspondence author. Email: carl.mitchell@wwt.org.uk

19th century, the distribution of Greylag Geese also contracted and numbers decreased, probably driven primarily by persecution from crofters and farmers.

By the 1870s the northwest Scotland (or 'native') Greylag Goose population was confined to the Uists, Harris & Lewis islands and small numbers on the adjacent mainland. By the 1930s, the number of Greylag Geese in Scotland possibly numbered no more than 500 birds, probably the lowest number in historic times (Berry 1939).

By the early 1960s the northwest Scotland population had increased somewhat to about 1000 birds, still confined mostly to the Outer Hebrides, with small numbers on the Scottish mainland in west Ross & Cromarty, west Sutherland and probably in Caithness (Atkinson-Willes 1963). Numbers increased and the range slowly increased, such that by the late 1980s, about 1500 were reported from Tiree & Coll, about 1600 from the Uists and about 2500 from Sutherland (Mitchell 1999). The first reported records of breeding Greylag Geese occurred in Orkney and Shetland in the mid 1980s. In 1997, a survey of the northwest Scotland population found about 10 000 geese, with peak concentrations on the Uists (3311 geese), Tiree & Coll (2366), Sutherland (1262) and Orkney (1114) (Mitchell *et al.* 2000). More recently, annual summer counts on Tiree & Coll, the Uists and Orkney have shown long-term increases in numbers. Ringing studies have confirmed that Greylag Geese breeding in Scotland are largely sedentary (Trinder *et al.* 2010).

Increases from the 1950s and 1960s were probably driven by a combination of protection (for all birds) under the 1954 Wild Birds Act which, for example, outlawed the taking of eggs and included the provision of protected areas. From the 1970s onwards, large areas of former rough hill ground in Scotland were subject to grant-aided intensive management and re-seeding, providing palatable, highly nutritious food in close proximity to potential Greylag Goose breeding areas. More recently, protection under the Wildlife & Countryside Act (1981) and recent reductions in winter severity and duration, have probably increased adult over-winter survival and enabled potential breeding females to attain better body condition prior to breeding in March. Hunting probably depressed the rate of increase in some areas, but faced with a potent mixture of favourable factors (see earlier), increases in numbers and range continued nonetheless. The number of hunters and the total shot may not have changed substantially and thus recruitment has increasingly outstripped mortality.

During the 1930s–1950s, a second population of Greylag Geese was re-established in Scotland (especially in Wigtown and Sutherland) and in England (Boyd & Matthews 1963). Geese were released in areas of former occurrence, mainly by wildfowling interests. Most geese were derived from the range of the northwest Scotland population, but it is possible that a very small number of Iceland-bred geese, taken in winter, were also involved (Boyd & Matthews 1963). From the late 1950s, Greylag Geese taken from existing re-established flocks were released in 10 more counties in England and Wales and in smaller numbers in parts of Scotland organized by the Wildfowlers' Association of Great Britain and Ireland (WAGBI, now the British Association of Shooting and Conservation, BASC).

Despite the disappearance of preferred habitat (natural fens, bogs and marshes) from much of Britain (although less so in Scotland), Greylag Geese showed themselves capable of using modified or new habitats for both breeding and wintering. By the late 1970s, they were firmly re-established as breeding birds in southwest and east-central Scotland, albeit in small numbers in the latter area. Brown & Dick (1992) estimated 2673 re-established Greylag Geese in Scotland in the late 1980s and early 1990s. Released birds remained in fairly discreet groups with little or no migratory movements. Dispersal and colonization of new sites appeared to be confined largely to sites in close proximity to the area of original release.

Evidence from the two Breeding Atlas surveys (Sharrock [1976] – henceforth referred to as the *1968–72 Atlas* and Gibbons *et al.* [1993] – the *1988–91 Atlas*) suggested that an increase in abundance and distribution of Greylag Geese from both the northwest Scotland and the re-established populations, had occurred between the two survey periods; the number of 10-km squares within which the species was recorded increased from 105 to 233. In the *1968–72 Atlas* there were no records of Greylag Geese from Tiree, Islay, Mull, Orkney, Shetland and large parts of central and upland Scotland. By the time of the *1988–91 Atlas* the range in Scotland had increased, but there were still no records from Islay, most of Skye and large parts of upland Scotland. Swann (2007) estimated about 20 000 summering Greylag Geese in Scotland in 2005, based on estimates from the core range.

Because of the recent increase in numbers and range of Greylag Geese in Scotland, it was also becoming increasingly difficult to establish their provenance. In the late 20th century, the gradual northward spread of the re-established stock in Scotland coincided with an increase

in the numbers and range of the northwest Scotland population. Mitchell *et al.* (2000) suggested that the two populations would meet and interbreed and that Greylag Geese, regardless of their provenance, would once again nest over much of Scotland. The authors suggested that future monitoring would probably necessitate a full survey of both populations and that continued ringing would help to monitor the progress and pace of integration.

In order to assess the current abundance and distribution of the species, a survey of summering Greylag Geese throughout Scotland was undertaken during 2008 and 2009. The objective was to survey Greylag Geese across the summering range. Specifically, this included assessing the population's size, distribution and reproductive success. The latter was measured indirectly through estimation of age ratios in the post-breeding population.

METHODS

The Great Glen forms a natural geographic feature running from Fort William to Inverness, which, at the time of the previous (1997) northwest Scotland Greylag Goose census (Mitchell *et al.* 2000), had also provided a convenient boundary to the population's distribution. For the present survey, checks of moulting flocks in early July (south and east of the Great Glen) were combined with late August surveys of post-breeding gatherings to the north and west following the methodology of Mitchell *et al.* (2000). The survey work was undertaken by Wildfowl & Wetlands Trust (WWT) staff and volunteer counters.

Moult-site survey in late June/early July

Consultation with key local birdwatchers indicated that the bird detection probability south and east of the Great Glen was likely to be greatest during the moulting period (late June/early July) when geese are more strongly associated with waterbodies and are most aggregated. These moult-sites are not necessarily those favoured for breeding. However, the determination of the breeding distribution of the population was a lower priority.

Counters visited each waterbody once between 22 June and 19 July in 2008 or 2009, recording numbers of adults and juveniles. The detection probability was taken to be 1.0, although this was not tested. No minimum time limit was set for site visits and counters could spend as much time as deemed necessary to check the site thoroughly for geese.

Priority sites – those expected to hold moulting geese – were identified through examination of county bird reports and liaison with WWT staff, WWT goose counter network, Royal Society for the Protection of Birds (RSPB) conservation officers/wardens, Scottish Ornithology Club (SOC) county bird recorders, and other relevant individuals. Two estuarine Greylag Geese moulting sites were visited: the Ythan Estuary in northeast Scotland and the River Esk at Musselburgh in east Scotland.

There are 805 lochs/waterbodies $\geq$5 ha in size, and 4638 lochs $<$5ha to the south and east of the Great Glen. Fifty-one lochs $\geq$5 ha and two lochs $<$5 ha were thought to hold moult flocks (see earlier) and were prioritized for checking, leaving 754 lochs/waterbodies $\geq$5 ha and 4636 $<$5 ha, from which a random stratified survey was carried out. At the 10-km square level a sampling methodology for lochs not identified as known moult-sites was derived to facilitate increased survey effort in areas with higher predicted occupancy by geese.

Analysis of the relationship between Centre for Ecology and Hydrology (CEH) remotely sensed Land Cover Map of Great Britain (LCM) data and Greylag Goose distribution data indicated that two of the nine broad land cover classes were particularly associated with the presence of Greylag Geese in a 10-km square: (1) a positive association with the proportion of water cover; and (2) a negative association with the proportion of woodland. These variables were, therefore, used as strata within the random stratified sampling. Two further strata were incorporated: the presence/absence of Greylag Geese within the 10-km squares (in which the centre of the waterbody lay) in the *1988–91 Atlas* and from recent records and a categorical altitude variable, 'lowland' (lochs $\leq$325 m altitude) and 'upland' ($>$325 m) (Appendix 1). The target sampling rates for lochs $\geq$5 ha ranged from 15% to 60% (total 34.2%) and for lochs $<$5 ha ranged from 1% to 10% (total 4%) (Appendix 1, Table A1).

A bootstrap method was used to derive population estimates for Greylag Geese in individual strata. Within each strata, n moult counts were randomly selected, with replacement, from the 2008 and 2009 data using 999 repetitions, where n equalled the number of lochs not visited in that strata. It was assumed that the probability of detection of geese was similar for all lochs. The n values for each stratum were summed to produce an estimate of the number of geese present in the unvisited lochs. This value was

added to the sum from the actual counts for that stratum to give a total population estimate. The 499th, 25th and 974th ordered bootstrap values were taken to give the median and lower and upper 95% CLs of the estimates, respectively (Appendix 1, Table A2).

Post-moult counts in late August

Counts of moulting birds are generally difficult in coastal areas of the north and west of Scotland, which is a key region for breeding Greylag Geese. On Tiree and North Uist, for example, Greylag Geese moult on very remote lochs (in areas where there are sometimes extensive pool complexes) or on the sea, making use of offshore islets for grazing. Therefore, in order to survey this region, post-moult counts were conducted during August, when the birds gather in large numbers, often on agricultural land. Counts were undertaken during the last three weeks of August 2008, except for Orkney (see later), and Caithness and Shetland, which were surveyed in 2009. Because of prior knowledge of Greylag Geese breeding on offshore islands off mainland Argyll, this area was also checked in late August 2008, although several inland lochs in Argyll formed part of the moult-site survey. Fieldworkers were encouraged to search all suitable areas for geese and submit all records of post-moult flocks. Although not systematic, this followed current field methods employed on the Uists and Tiree & Coll (searching suitable habitats). However, it was recognized that this 'look-see' approach was likely to represent a minimum count estimate (see Discussion). Following submission of records, potential duplicates were excluded. For example, where two (or more) flocks were reported from the same area on separate occasions, and duplication was suspected, the highest count was used.

On Orkney, Eric Meek (RSPB) suggested that counting Greylag Geese in August might be problematic. Unlike much of north and west Scotland, Orkney comprises a large area of agricultural land, including managed grassland and arable stubbles. Local knowledge suggested that a more reliable count might be achieved during the moult period in July 2008, necessitating counts of waterbodies as well as boat-based counts of offshore areas.

Breeding success

In 2008, counters were asked to age a representative sample of birds and collect brood size data where possible. Adults and goslings can be separated when viewed through a telescope by examination of wing coverts and contour feathers.

RESULTS

Moult-site survey in late June/early July

Forty-one of the 53 known moult-sites checked held a total of 8008 geese (median 67 birds, excluding zero counts), while 12 lochs held no geese (Appendix 2 gives the highest counts). The total number included 6163 adults and 633 goslings (9.3% young), while 1212 birds were not aged. Eleven lochs held flocks consisting entirely of non-breeding adults (median 49 birds) and a further five lochs held flocks comprising more than 90% adults. Four lochs held flocks of geese that were not aged (346, 159, 36 and 1 bird, respectively).

A total of 494 lochs were checked for the random stratified survey: 246 lochs from the 754 lochs $\geq$5 ha (a sampling rate of 32.6%) and 248 lochs from the 4636 lochs $<$5 ha (5.3%). Forty-nine of the 494 lochs checked during the random stratified survey (10%) held a total of 1126 geese, the median count being 13 birds (Appendix 2 gives the highest counts). Of the 49 lochs that held geese, the majority (59.1%) were sites where Greylag Geese had bred in small numbers, either at the site or locally (determined by the presence of goslings in the flocks encountered). The remaining 445 lochs (90.1%) that were checked held no geese. The distribution of the lochs checked revealed concentrations of birds in southeast Highland, Upper Forth, Lothians and Galloway (Fig. 1).

The bootstrap analysis of the random stratified survey estimated that there were 1966 (95% CI: 1448–2631) Greylag Geese on lochs $\geq$5 ha and 2921 (95% CI:1236–4914) geese on lochs $<$5 ha (Table 1).

The median altitude of the 90 waterbodies holding moulting geese was 162 m asl (maximum 417 m), although this included two estuarine sites (i.e. at sea level). The median size of waterbody was 32.5 ha (excluding the two estuarine sites), with the majority (61.4%) being $<$50 ha in size. Six lochs holding geese were greater than 500 ha, the largest being Loch Leven, Perth & Kinross (1371 ha).

Post-moult counts in late August

The largest counts of Greylag Geese were from Orkney (about 10 000 geese), the Uists (5948), Tiree (3370),

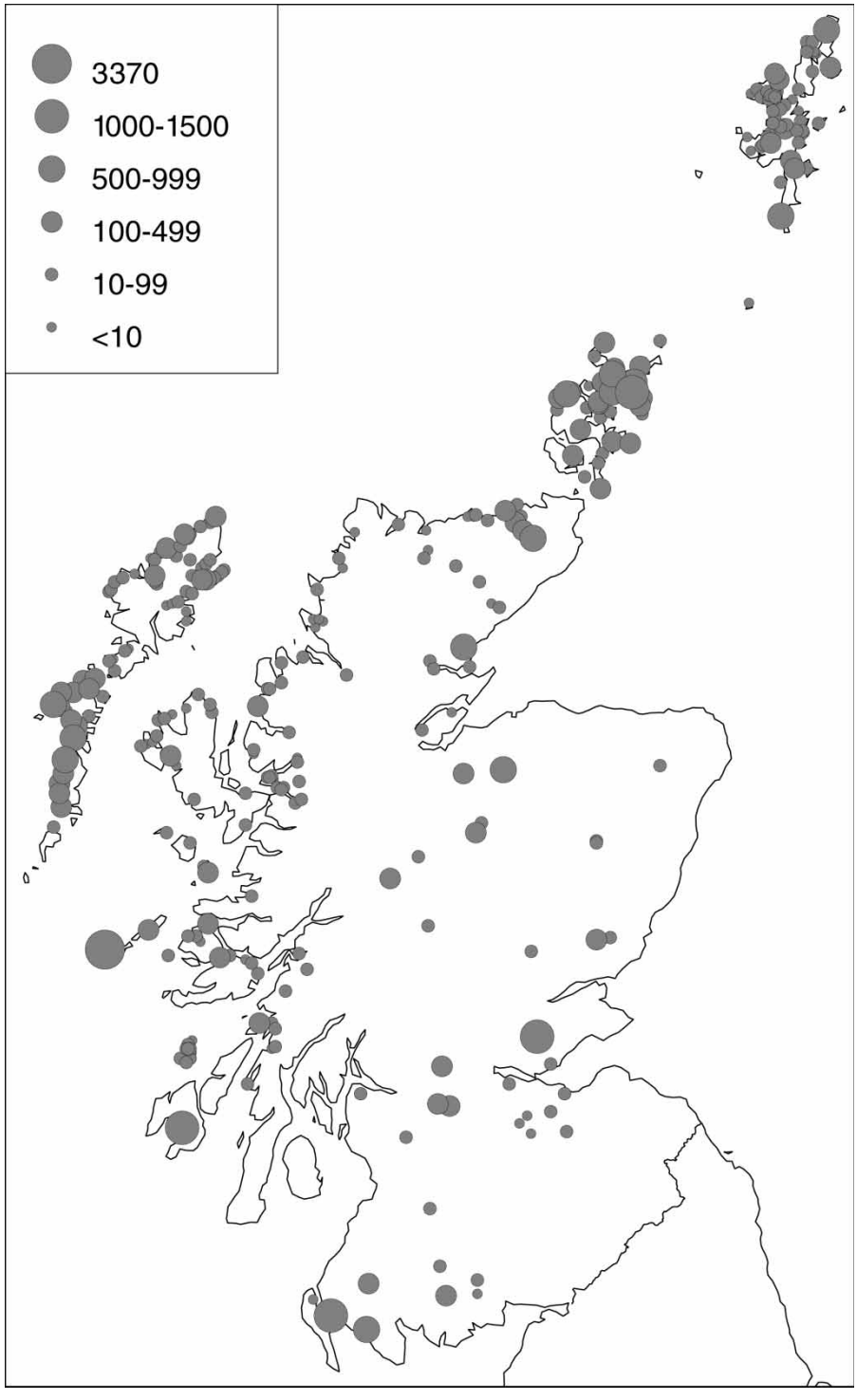

Figure 1. Distribution of Greylag Geese encountered during the 2008–09 survey of Scotland.

Shetland (about 4633), Harris & Lewis (1912), Islay (about 1500) and Sutherland (1000) (Fig. 1; Appendix 3).

Population estimate and distribution

The 2008–09 population estimate was thus 47 405 geese (95% CI: 44,059–51,763; Table 1), with the largest

Table 1. Summary of counts from the known moult-site survey, random stratified survey including estimates from the bootstrap analysis and post-moult counts.

	No. lochs	No. lochs checked	No. lochs holding geese	No. geese counted	No. geese estimated from bootstrap analysis*	Estimate	Range (95% CI)
Known	53	53	41	8008		8008	8,008
≥5 ha	754	246	40	823	1966	1966	1448–2631
<5 ha	4636	248	9	303	2921	2921	1236–4914
Post-moult counts				34 510		34510	33 367– 36 210
Total						47405	44 059–51 763

*the number of geese is the median from bootstrap estimate for samples

Table 2. Breeding success of Greylag Geese in Scotland in 2008.

Month	Area	Region	Adult	Young	% young	No. broods	Mean brood size
July	Known moult sites	S&E Scotland	5417	631	10.4	67	3.97
July	Random stratified survey (>5 ha)	S&E Scotland	584	267	31.4	48	3.77
July	Random stratified survey (<5 ha)	S&E Scotland	100	66	39.8	16	3.69
July	Orkney	N&W Scotland				116	3.64
August	Post-moult counts	N&W Scotland	2615	1804	40.8	481	2.89
Total			8716	2768	24.1	728	3.19

concentrations in Orkney, the Uists, Tiree, Shetland, Harris & Lewis, Islay, Sutherland, Galloway and Perth & Kinross (Fig.1).

Breeding success

In 2008, there was 24.1% young overall and the mean brood size was 3.19 goslings per successful pair (Table 2). There was a statistically significant difference in regional breeding success ($\chi^2 = 1120$, df = 2, $P < 0.01$), with relatively low success in south and east Scotland (15.8% for the known moult-sites and random stratified survey sites combined) compared with high success of 40.8% in north and west Scotland.

DISCUSSION

We estimated about 34 500 Greylag Geese in the north and west Scotland population in 2008–09 (Table 1), an increase of 245% on the 1997 estimate of about 10 000 birds (Mitchell *et al.* 2000); an average rate of increase of 11.9% per annum. We also estimated about 12 900 Greylag Geese in the area south and east of the Great Glen in 2008–09 (Table 1), the area traditionally regarded as the range of the re-established population. This represents an increase of 382% since the estimated post-breeding population of about 2673 birds in 1991 (Brown & Dick 1992); an average annual rate of 9.7%.

Owen and Salmon (1988) estimated an annual rate of increase of about 13% for re-established Greylag Geese in Britain as a whole during the period 1966–88. In 2000, there were an estimated 24 500 re-established Greylag Geese in Britain (including Scotland) and numbers were increasing at an average rate of 9.4% per annum (Austin *et al.* 2007), similar to that for re-established Greylag Geese in the current study. The annual index based on the Wetland Bird Survey shows a period of continued increase in numbers since the 1990s (Austin *et al.* 2008) and, assuming a continued rate of annual increase (9.4% per annum), the number of re-established Greylag Geese in Britain was likely to have risen to about 50 000 birds by 2008. Combining that estimate with the number of Greylag Geese recorded in north and west Scotland in the current study (about 34 500 birds) suggests the total number of Greylag Geese summering in Britain is probably about 84 500 birds.

The survey of waterbodies to the south and east of the Great Glen previously holding summering/moulting geese (known sites) produced a count of about 8000 Greylag Geese, yet nearly a quarter (12 of 53 sites checked) held no geese. A small number of key sites held the majority of geese, with the top five sites alone accounting for about 57% of the total counted (Appendix 2), the majority of which were non-breeding adults.

The random stratified survey of waterbodies to the south and east of the Great Glen achieved 32.6% coverage of lochs ≥5 ha and 5.3% coverage of lochs <5 ha.

Because of the highly aggregated distribution, with a few lochs holding large flocks, the count of 4887 Greylag Geese was estimated with low precision (95% CI: 2684–7545; Table 1). The majority (90.1%) of the 494 waterbodies checked held no geese.

The south and east Scotland survey did not include possible moulting sites on estuaries, river systems or upland mires/wetland complexes with no defined waterbodies. There are few recorded instances of geese moulting on estuarine sites (Scottish Bird Reports), and the two known sites, the Ythan Estuary and the River Esk, were counted. Moult gatherings on river systems or upland mires/wetland complexes are also poorly documented (or involve few birds). Undoubtedly small numbers of geese do use such habitats to moult, and birds could be present in small numbers over a wide geographic range. However, there are no recorded examples of large gatherings (Scottish Bird Reports). While the number of geese involved is thought to be low, future surveys should include a sample of these three habitats.

The ideal objective of this survey was to generate a reliable population estimate and an assessment of the variance of the estimate to enable comparison with future surveys. However, north and west Scotland has about 18 000 lochs and using a random stratified approach and achieving adequate coverage would have been logistically difficult and expensive. Relying on counts in August, after the geese have left remote breeding areas to gather at lower altitude, often on agricultural land, produced a minimum estimate, once potential duplicate counts had been removed. This is the method currently employed for annual counts on the Uists and Tiree & Coll as constrained by cost. While small numbers of isolated geese may have been missed in the more remote areas, particularly of Ross & Cromarty, Sutherland and Lochaber, discussions with county recorders, RSPB and Scottish Natural Heritage (SNH) staff and local birdwatchers, and through personal informal checking of some of these areas, suggest that few flocks are known to occur in these areas at this time of year. However, in order to enable statistically robust comparative surveys in the future, and to establish rates of population change in different regions, funding needs to be in place to enable a random stratified approach to be undertaken throughout Scotland.

Evidence from ringing suggests that the likelihood of movement between the two regions during the survey interval (early July and late August), and thus the likelihood of birds being missed or counted twice was low. Greylag Geese in north and west Scotland appear to be relatively sedentary. The median recovery distance of Greylag Goose goslings hatched (and ringed) in Britain was 10 km ($n = 28$ [Swann & Brockway 2002]). On Tiree & Coll, of 1115 Greylag Geese ringed during the summer, 184 were recovered dead and most (98%) were shot within Tiree/Coll (Trinder *et al* 2010). Only four geese were recovered elsewhere in Scotland, mostly in nearby areas. Very few relatively long-distance Greylag Goose moult migrations are known in Britain. Some individuals from southwest England (principally Gloucestershire) and south Wales moult in the Hogganfield Loch area, near Glasgow, during July and August (WWT, unpubl. data). Evidence for other such movements is sparse, and, nationally, may involve relatively few birds, but few breeding Greylag Geese in England and Wales have been marked and so there is a lack of ring recoveries.

Given the sedentary nature of the stock, colonization of new areas probably occurs at a rather modest rate, although once such colonization does occur (assuming favourable breeding and feeding conditions), population growth can be quite rapid. Assuming an average growth rate of about 12%, a pioneering population of 200 birds can increase to about 2000 in about 20 years. A good example of the rapid rate of colonization comes from Tiree. Local crofters suggest that no geese were breeding on Tiree in the 1950s, so colonization, possibly from the Uists, probably occurred in the 1960s. By November 1985, numbers had increased to 710 (Stroud 1989) and 20 years later, in 2005, there were 3510 birds, a growth rate of about 8.8% per annum. Similar rapid increases have occurred on Orkney and Shetland, where the first confirmed breeding attempts were noted in the mid 1980s; prior to that, summering birds were virtually absent. By the late 2000s, Orkney and Shetland supported about 10,000 and about 5000 breeding geese, respectively. The causes of the difference in rates of increase in each area are unknown but may reflect high hunting mortality on Tiree (Trinder *et al* 2010).

It is possible that differences in survey methodology used in the two areas may have affected the breeding success rates reported. For example, moult gatherings on larger waterbodies (>5 ha), a greater proportion of which were surveyed, may be favoured by failed and non-breeders, thus depressing the estimate of breeding success. Breeding success varied across Scotland, although the overall rate recorded in 2008, of about 24%, presumably more than compensates for mortality. At the present rates of annual recruitment and mortality, the population will likely continue to increase, especially in the north and west of Scotland. In areas to the south

and east of the Great Glen, Greylag Geese were not found on any waterbodies above 417 m asl and only 5.6% of lochs holding geese were over 325 m asl. Thus, despite being relatively safe, undisturbed and occasionally with marginal grazing opportunities, high ground does not currently prove attractive to post-breeding birds.

The surveys in 1997 and 2008–09 involved a 'look see' approach in areas to the north and west of the Great Glen. However, the numbers of summering Greylag Geese have increased to such a level that future post-breeding estimates of population size and distribution could concentrate on surveying a reduced stratified sample on a regular basis. In terms of providing the most statistically reliable indicators, rates of change (with associated confidence intervals) are preferable to potential underestimates caused by not surveying new areas of colonization. Given the estimated rates of increase in the abundance of Greylag Geese in Scotland, it is important that the population estimate is updated regularly. Given the high political status of the species and the related management issues resulting from increases in goose populations, future surveys should, if possible, be coordinated with survey effort elsewhere in the range of British Greylag Geese. The results of the 2008–09 survey are timely since a review of goose management within Scotland will take place in 2010–11. Together with information on the population dynamics of Greylag Geese breeding in Scotland (Trinder *et al.* 2010) these results will enable the Scottish Government to formulate future goose management policy.

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APPENDIX 1. RANDOM STRATIFIED SURVEY METHODOLOGY AND RESULTS

Altitude

A prior analysis had shown that the median altitude of the 51 known moult-sites was 167 m and that no moulting geese had been recorded on lochs above 325 m. Two strata were used: lochs below, or equal to, 325 m (Low); and lochs above 325 m (High).

Presence/absence of geese

Several data sources were used to determine the recent distribution of Greylag Geese in Scotland: the *1988-91 Atlas*; the 2007 RSPB Common Scoter *Melanitta nigra* breeding survey; June and July records from the RSPB Merlin bird database; County Bird Reports. Any summer records of Greylag Geese from these sources were summed by 10-km square. Two strata were used: 10-km square with no geese present (absent) and 10-km square with Greylag Geese present (present).

Habitat data

The Centre for Ecology and Hydrology (CEH) remotely sensed 'Land Cover Map of Great Britain' (LCM) provided data on nine broad habitat classes: arable; improved grassland; semi-natural grassland; broadleaf and conifer woodland; sea; upland/moorland; built-up areas; coastal areas; and water. Correlations between the LCM data and the number of Greylag Geese found in the presence/absence analysis (earlier), summarized at the 10-km square level, showed a significant positive relationship with the presence of water within the 10-km square and a significant negative relationship with the amount of woodland cover (conifer and broadleaf combined).

Using the median value (including zeros) of the amount of woodland in each 10-km square, two strata were used: 10-km square with less than 1260 ha woodland (low) and 10-km square with more than 1260 ha woodland (high). Similarly, using the median value of the amount of water in each 10-km square, two strata were used: 10-km squares with less than 24 ha water (low) and 10-km squares more than 24 ha water (high).

Each loch/water-body was assigned to a 10-km square using the central grid reference of the loch. It was then possible to assign each loch a stratum score:

- 1, low-altitude lochs; 0, high-altitude lochs
- 1, presence of Greylag Geese in the associated 10-km square; 0, absence of Greylag Geese
- 1, high proportion of water in the associated 10-km square; 0, low proportion of water
- 1, low proportion of woodland in the associated 10-km square; 0, high proportion of woodland

In 2008, surveillance concentrated on lochs $\geq$5 ha and in 2009 on lochs $<$5 ha. Given the sedentary nature of Greylag Geese it seemed reasonable to allow this approach. Target surveillance rates were different: a lower surveillance rate for the lochs with the lowest strata scores and a higher surveillance rate for the lochs with the highest strata scores. The surveillance rates were chosen from the combined strata (Table A1) and the results of the surveillance are shown in Table A2.

Table A1. Target and actual surveillance rates for each of the five strata scores of lochs surveyed in 2008 and 2009.

Stratum score	Target surveillance rate	No. lochs	Target sampling rate	Target no. lochs to check	Actual sampling rate
2008 (lochs $\geq$5 ha)					
Known	High	51	100%	51	51 (100%)
0/1	Low	151	15%	23	29 (19.2%)
2	Med	318	25%	80	87 (27.4%)
3	Med/high	244	40%	98	106 (43.4%)
4	High	41	60%	25	24 (58.5%)
Total		805	34.2%	277	297 (36.9%)
2009 (lochs $<$5 ha)					
Known	High	2	100%	2	2 (100%)
0/1	Low	1224	1%	12	20 (1.6%)
2	Med	1690	2%	34	35 (2.1%)
3	Med/high	1397	7.5%	105	152 (11.0%)
4	High	325	10%	33	41 (12.6%)
Total		4638	4.0%	186	250 (5.4%)

Table A2. Extrapolated estimates using bootstrap analysis for individual strata during 2008 and 2009.

Altitude	Presence/ absence of geese	Woodland cover	Water cover	No. lochs in stratum	No. sampled	Lower 95%	Mean	Upper 95%	Extrapolated estimate
2008 (lochs ≥5 ha)									
High	Present	High	High	41	12	30	103.2	220.9	102.5
High	Present	High	Low	5	1	35	35	35	35
High	Present	Low	High	6	4	55	80.6	107	81
High	Present	Low	Low	0	0	–	–	–	–
High	Absent	High	High	57	10	0	0	0	0
High	Absent	High	Low	5	0	–	–	–	–
High	Absent	Low	High	60	8	0	0	0	0
High	Absent	Low	Low	15	1	0	0	0	0
Low	Present	High	High	206	90	988	1397.8	1912.2	1403.1
Low	Present	High	Low	25	3	0	0	0	0
Low	Present	Low	High	41	24	4	6.8	11.1	6.8
Low	Present	Low	Low	8	0	–	–	–	–
Low	Absent	High	High	178	60	95.9	280.6	634.8	278.9
Low	Absent	High	Low	69	17	8	32.4	72.3	32.5
Low	Absent	Low	High	24	12	13	25.7	52	26
Low	Absent	Low	Low	14	4	0	0	0	0
Total						1224.9	1962.1	3045.3	1965.8
Overall estimate						1448	1966	2631	
2009 (lochs <5 ha)									
High	Present	High	High	139	0	–	–	–	–
High	Present	High	Low	45	0	–	–	–	–
High	Present	Low	High	134	3	0	0	0	0
High	Present	Low	Low	8	0	–	–	–	–
High	Absent	High	High	311	4	0	0	0	0
High	Absent	High	Low	106	1	0	0	0	0
High	Absent	Low	High	348	8	0	0	0	0
High	Absent	Low	Low	230	4	0	0	0	0
Low	Present	High	High	711	100	7	48.8	135.3	49.8
Low	Present	High	Low	127	7	16	277.1	838.9	290.3
Low	Present	Low	High	325	41	103	802.2	2132.6	816.5
Low	Present	Low	Low	210	35	205	885.3	1785	900
Low	Absent	High	High	559	13	11	482.7	1397	473
Low	Absent	High	Low	532	11	0	0	0	0
Low	Absent	Low	High	343	14	16	403.3	1144	392
Low	Absent	Low	Low	508	7	0	0	0	0
Total						358	2899.4	7432.8	2921.6
Overall estimate						1236	2921	4914	

APPENDIX 2. THE SIX HIGHEST COUNTS OF GREYLAG GEESE FOUND DURING THE KNOWN MOULT-SITE SURVEY AND THE RANDOM STRATIFIED SURVEY IN SOUTH AND EAST SCOTLAND IN SUMMERS 2008 and 2009.

Site	Year of count	Recording area	No. Greylag Geese
Known moult-sites			
Black/White Lochs	2008	Dumfries & Galloway	1395
Loch Leven	2008	Perth & Kinross	1014
Lochindorb	2008	Highland	784
Clatteringshaw Loch	2009	Dumfries & Galloway	723
Castle Loch	2008	Dumfries & Galloway	680
Loch Moy	2008	Highland	480
Random stratified survey			
North Third Reservoir	2008	Upper Forth	113
Cults Loch	2008	Dumfries & Galloway	104
Carron Valley Res.	2008	Upper Forth	99
Loch Dubh	2009	Highland	87
Loch Duntelchaig	2008	Highland	85
Gosford Loch	2009	Lothians	62

APPENDIX 3. THE NUMBER OF GREYLAG GEESE RECORDED DURING POST-MOULT COUNTS IN SCOTLAND, AUGUST 2008.

Count area	Region	Count	Range[1]
Isle of Bute	Clyde Islands	528	
Isle of Arran	Clyde Islands	24	
Tiree	Argyll	3370	
Coll	Argyll	278	
Mainland Argyll[2]	Argyll	683	
Islay	Argyll	1500	1457–1600
Mull	Argyll	743	
Colonsay	Argyll	324	
Treshnish Isles	Argyll	80	
Uists	Outer Hebrides	5948	
Barra	Outer Hebrides	90	
Harris & Lewis	Outer Hebrides	1912	
Skye	Highland	536	
Lochalsh	Highland	284	
Rum/Eigg/Muck/Canna	Highland	478	
Lochaber	Highland	51	
Ross & Cromarty	Highland	848	
Sutherland	Highland	1000	
Caithness[3]	Caithness	1200	1100–1300
Orkney[4]	Orkney	10,000	9000–11 000
Shetland[3]	Shetland	4633	4633–5133
Total		34 510	33 367 – 36 210

[1]In four areas (Mainland Argyll, Caithness, Orkney and Shetland) a range of values was given as the estimate of the total number of Greylag Geese present; [2]coastal mainland Argyll from Machrihanish to Oban only (Inland lochs formed part of the stratified survey); [3]Shetland and Caithness were counted in August 2009; [4]Orkney was counted in July 2008.