An approach to the assessment of change in the numbers of Canada Geese *Branta canadensis* and Greylag Geese *Anser anser* in southern Britain

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Capsule Population change in geese was assessed using an approach that requires a relatively small sampling effort.

Aims During the 1999 breeding season a survey was carried out to determine if the numbers of introduced Canada and re-established Greylag Geese in southern Britain had changed since 1988–91 and whether any change had occurred in areas with previously high or low Canada Goose densities.

Methods A randomized stratified sample of 246 tetrads from the 24 156 tetrads covered between 1988–91 in this area, as part of the *New Atlas of Breeding Birds*, were resurveyed. Eight habitat categories were used in the stratification and were based on 1-km-square summary data obtained from the CEH Land Cover Map of Great Britain (water cover and urbanization) and LANDCLASS stratification (upland/lowland). The five habitat categories with the highest densities of Canada Geese and the greatest variance in numbers were sampled.

Results Between 1989 and 1999, the number of Canada Geese on land with over 5% water cover and on lowland with some water cover increased by on average 156%, an average rate of increase of 9.9% per annum. Southern Britain probably now holds a minimum of 82 000 Canada Geese. Between 1989 and 1999, the number of Greylag Geese on land with over 5% water cover and on lowland with some water cover increased by on average 214%, an average rate of increase of 12% per annum. Southern Britain probably now holds a minimum of 30 000 Greylag Geese.

Conclusion Maximum densities of Canada Geese may have been reached in high-density habitats but their numbers are still increasing very rapidly. Greylag Geese are increasing even more rapidly.

During the 1999 breeding season, a survey of the Canada Goose *Branta canadensis* and re-established Greylag Goose *Anser anser* in southern Britain looked for evidence of change in abundance since *The New Atlas of Breeding Birds in Britain and Ireland: 1988–91* in 1991 (Gibbons *et al*. 1993). The survey covered an area that had historically held the main concentrations of these geese, from south of Newcastle-upon-Tyne (England) to the east of Brecon (Wales).

The Canada Goose is the most numerous goose in the world, introduced from its native North America both to Europe and Australasia. First introduced to the waterfowl collection of Charles II in Britain in 1665 (Madsen *et al*. 1999), by 1991 44 400 (40 716–48 364) Canada Geese were found in most 10-km squares containing some open water in an area south of Newcastle-upon-Tyne (England) to east of Brecon (Wales). Wetland Bird Survey (WeBS) data show that, between 1960–61 and 1984–85, the UK Canada Goose population increased at 9.8% per annum, but slowed down to 2.4% per annum by 1991 (Kirby *et al*. 1996). During 1991 it was estimated that there were 61 000 individuals of which 46 700 were known to be adults (Delany 1993, Stone *et al*. 1997). Gibbons *et al*. (1993) estimated that there were 59 500 adult individuals in Britain and Ireland between 1988–91, the large majority of which were in Britain. Although showing major annual fluctuations, since 1987–88 the WeBS Canada Goose population indices in Great Britain have levelled off, and yet the peak national total is a third higher than ten years previously (Pollitt *et al*. 2000). This inconsistency may suggest that much of the population growth of Canada Geese might be occurring on new or small sites not usually surveyed by WeBS or that

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have not been surveyed for long enough to contribute to the national index. This uncertainty makes it important that periodic surveys assess the extent of numerical change.

The Greylag Goose, as the only native breeding goose in Britain, is now largely confined to the Western Isles and Northern Scotland. Between 1930 and 1970 flocks were re-established in many parts of Britain, sometimes as a result of introductions by wildfowling interests (Owen *et al*. 1986). Between 1968–72 (Sharrock 1976) and 1988–91 (Gibbons *et al*. 1993), the reintroduced birds had spread rapidly over much of England. By 1991, 11 737 re-established adults were recorded in Britain, with a further 2856 unaged birds (Delany 1993). Gibbons *et al*. (1993) estimated 22 000 adult individuals in Britain and Ireland between 1988–91. Based on these estimates 12 351 (10 363–14 650) adult Greylag Geese were likely to be found in the area surveyed during 1999. Since 1988–89 WeBS records a 100% increase in 'naturalized' Greylag Geese (Pollitt *et al*. 2000).

Canada and Greylag Geese cause damage to agriculture and amenity sites, they can contribute to eutrophication of water-bodies and are a risk to human health (Allan *et al*. 1995, Dawson & Evans 1996, Manny *et al*. 1994, Watola *et al*. 1996). In extreme cases they lead to total loss of root crop and cereal yield but more normally 50% or less is lost (Owen *et al*. 1986). Canada (up to 5.4 kg) and re-introduced Greylag Geese (up to 4.6 kg), being large birds that are quite tame and largely unaffected by disturbance such as noise, are a threat to air safety and have been involved in bird strikes in Britain and the Americas (Watola *et al*. 1996).

The 1999 pilot Goose Population Change Survey was designed primarily to assess, from a relatively small sampling effort in high-density Canada Goose habitat, whether the numbers of Canada and Greylag Geese in the surveyed area had changed since 1991 (Gibbons *et al*. 1993) and whether such changes were consistent across habitat types and previous goose densities. The accuracy of the population estimates generated using this approach will be tested by a full survey in 2000.

METHODS

Between 1988 and 1991, the British Trust for Ornithology and Irish Wildbird Conservancy mapped the distribution of all bird species breeding in Britain and Ireland (Gibbons *et al*. 1993). The survey data for this *Breeding Atlas* were based on tetrad (2 km × 2 km) count units selected at random from 10 × 10-km squares of the Ordnance Survey national grid (Fig. 1). This helped avoid any potential bias that might be caused by observer choice. Within each 10-km square a minimum of eight tetrads were visited, observers spending up to two hours in each tetrad either as a single visit or as two one-hour visits, one early in the season (April–May) and one late (June–July). The higher count of each species was used to estimate national populations and regional variation in abundance.

Narrowing the geographical scope of survey

To avoid unnecessary sampling of areas where Canada and re-established Greylag Geese are rare, the 1999 Goose Population Change Survey was restricted to the core distribution of the target species, an area south of Newcastle-upon-Tyne (England) and east of Brecon (Wales) between 1988 and 1991 (Fig. 1). The remainder of the survey design was based on the Canada Goose distribution between 1988–91 as it was considered the priority species.

Identifying homogenous habitat units to minimize within-stratum variance

The Centre for Ecology and Hydrology (CEH) remotely-sensed *Land Cover Map of Great Britain* data and the CEH LANDCLASS stratification, summarized in units of 1-km^2, made it possible to divide the 1999 Goose Population Change Survey sampling area into a variety of habitat categories or strata (Appendix 1). The habitat data from the relevant four 1-km^2 summaries were matched with each *Breeding Atlas* tetrad.

Exploratory analyses showed that two of the 25 land cover classes were particularly important in determining the numbers of Canada Geese in a tetrad: 'the proportion of water cover' and 'the proportion of urbanization'. A further division into 'lowland' and 'upland' according to land characteristic classes based on the CEH LANDCLASS stratification (Appendix 1) helped further minimize within-stratum variance.

Refining habitat definitions to maximize between-stratum differences

Once these broad divisions had been identified, the proportion of water and urbanization in each was subdivided into high, low and none, and the three classifications superimposed to give a potential 18 strata.

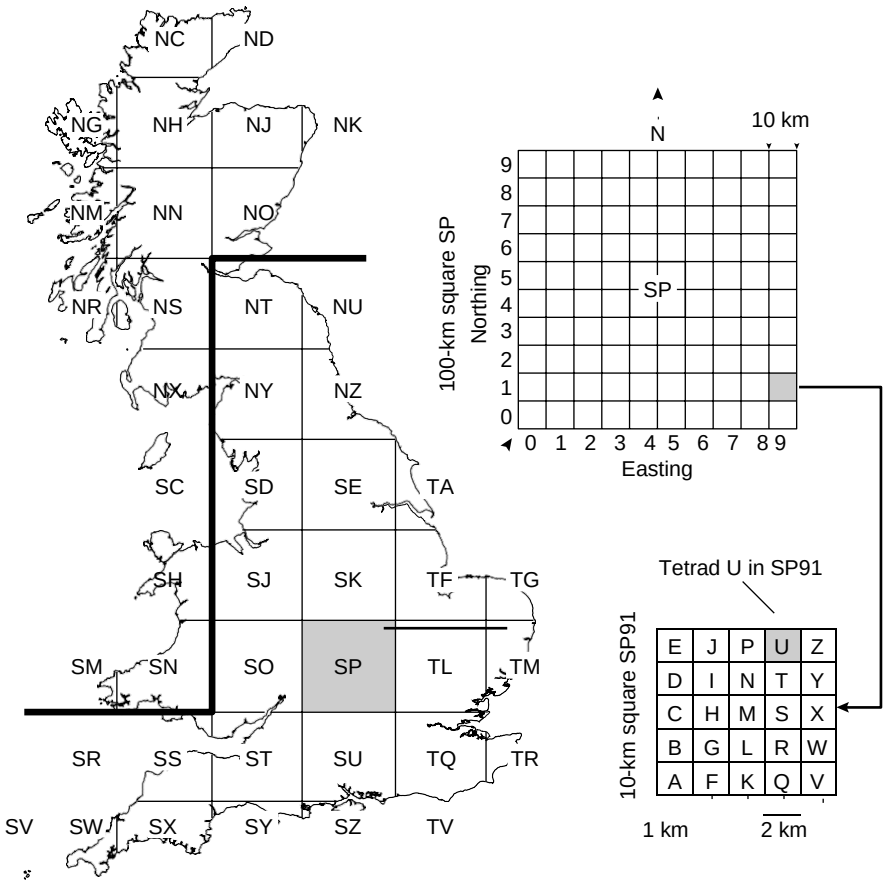

Figure 1. The areas of Britain sampled during the 1999 Goose Population Change Survey are south of the thick black line. The letter designations of the 100-km squares of the British grids, and the method of determining 10-km square and tetrad grid references are presented. Tetrad U in 10-km square SP91 is given as an example. Figure adapted from Gibbons *et al. (*1993).

The limits of the boundaries of the sublevels of the water and urban cover divisions were adjusted in an iterative manner to minimize the within-stratum variances and maximize the between-stratum differences in the number of Canada Geese each had contained during 1988–91. The number of strata was reduced by combining highly urbanized, urbanized and rural areas into 'lowland with some water cover', 'lowland with no water cover' and three upland categories. This reduced the number of strata from 18 to eight, all relatively common, with relatively small within-stratum variances and relatively large between-stratum differences (Table 1).

Estimating the sample size necessary to detect a 10% population change

The number of tetrads resurveyed affects the likelihood of detecting a certain size of change in population size: the smaller the sample the less likely that a small population change will be detected.

The sample size required to detect a 10% population change with 95% confidence in the surveyed area was estimated following Greenwood (1996) from the *Breeding Atlas* distribution of Canada Goose numbers recorded in units of one tetrad. An implicit assumption of this approach was that the frequency distribution of change was similar to the frequency distribution of Canada Geese during 1988–91. It is unlikely that this approach is without bias as density-dependent factors were likely to start operating on the strata with the highest goose densities, but in the absence of better information this approach was the most appropriate. By allocating tetrads optimally to minimize the variance within the eight strata it was estimated that by surveying 250 tetrads in five strata a 10% increase in Canada Goose population size could be detected with 95% certainty.

Targeting sampling effort appropriately

The optimal allocation of tetrads had to be modified

Table 1. The distribution of Canada Geese as recorded by the *Breeding Atlas* in the eight strata used to stratify the 1999 Goose Population Change Survey. In each data cell the top line gives the mean number of Canada Geese per tetrad between 1988–91 followed by the percentage of tetrads with geese in parentheses. The second line in each data cell gives the number of tetrads of each stratum habitat type (*n*) in Great Britain followed by the proportion of Great Britain's Canada Geese found in each stratum between 1988–91. The individual strata are determined from the CEH *Land Cover Map of Great Britain* and LANDCLASS stratification.

		Land characteristics		
			Lowland	
Water cover	Upland	Highly urbanized ≥5%	Urbanized 5%>urban>0%	Rural 0%
Much water cover ≥5%	6.5 (25%) *n* = 1 353 (12%)	38 (47%) *n* = 97 (5%)	21 (60%) *n* = 195 (5%)	27 (42%) *n* = 215 (8%)
Some water cover 5%>water cover>0%	1.9 (17%) *n* = 3 615 (9%)		6.8 (34%) *n* = 2 982 (27%)	
No water cover 0%	0.1 (2%) *n* = 18 768 (3%)		0.7 (8%) *n* = 34 275 (32%)	

slightly, as the required number of tetrads was not always available in each stratum (Table 2). For example, the optimal allocation suggested that 52% of the survey sample or 130 tetrads should be from the 'highly urbanized lowland with much water cover' stratum, but only 61 were available for resampling. The intensive selection of this stratum was due to the high goose density and variance on this habitat (Table 3).

The adapted optimal allocation of tetrads led to a randomized stratified sample of 246 of the 24 156 tetrads covered between 1988–91 in the 1999 survey area being selected for resurvey (Table 2, Fig. 2). These 246 tetrads were from the five habitat strata that had held the highest densities of Canada Geese (and re-established Greylags) during 1988–91: 'upland with much water cover', 'highly urbanized lowland with much water cover', 'urbanized lowland with much water cover', 'rural lowland with much water cover' and 'lowland with some water cover'. Due to Canada Geese being found at low average densities and on a small percentage of the three unsampled strata it would have required a considerable increase in sampling effort to sample all of these strata. For example, only 1.98% of 'upland with no water cover' tetrads held any Canada Geese during 1988–91. A simulation based on this new sample demonstrated that it met the criterion for detecting the required level of population change in Canada Geese.

Table 2. The proportion of the Breeding Atlas tetrads in each stratum covered during the 1999 Goose Population Change Survey. In each data cell the top line lists the proportion of the Breeding Atlas tetrads covered by the 1999 survey followed by the number of tetrads covered during 1999 in parentheses, and the bottom line lists the optimal allocation followed by the actual allocation of tetrads. The values in this table refer to the area of Britain covered by the 1999 survey (Fig. 1).

		Land characteristics		
			Lowland	
Water cover	Upland	Highly urbanized ≥5%	Urbanized 5%>urban>0%	Rural 0%
Much water cover ≥5%	20% (25) 10% vs 2%	93% (57) 23% vs 52%	45% (70) 28% vs 14%	97% (69) 28% vs 28%
Some water cover 5%>water cover>0%	0% (0) 0% vs 0%		1% (25) 10% vs 2%	
No water cover 0%	0% (0) 0% vs 0%		0% (0) 0% vs 0%	

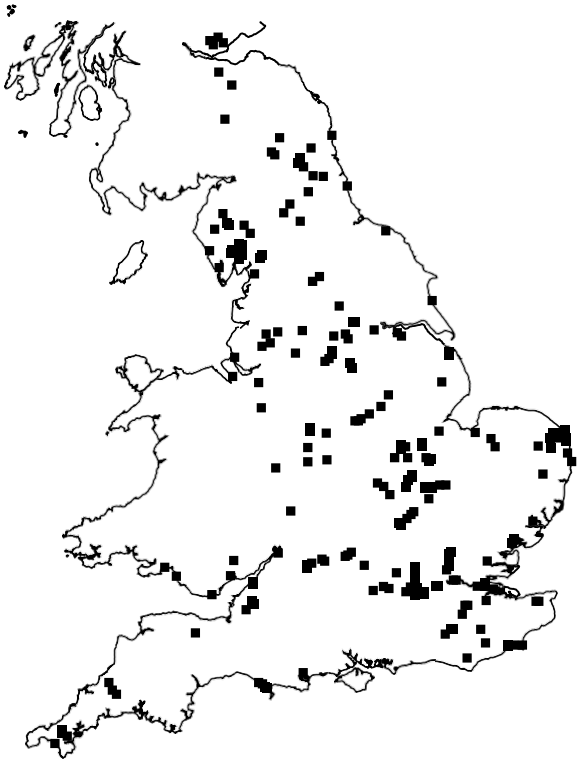

Figure 2. The 246 tetrads sampled during the 1999 Goose Population Change Survey.

The survey

From mid-April to mid-June 1999, the randomly selected tetrads were surveyed following the methodology used by Gibbons *et al*. (1993). The random tetrads were chosen from those previously counted for the *Breeding Atlas* to enable an unbiased, paired comparison of counts made during the two surveys to be made. Counters spent 30 minutes in each of the four 1-km square units of the tetrad, a maximum of two hours in each tetrad. Areas that were totally unsuitable for geese within a tetrad (densely built up areas with no still or running waters, dense forest, etc.) were not covered and the time adjusted accordingly. Hence if one 1-km square unit within a tetrad was totally unsuitable for introduced and re-established geese, the counters would only spend one and a half hours in the tetrad. Counters recorded the areas covered. All geese were recorded, adults separately from young birds. Flying birds were not counted unless seen taking off from or landing in the tetrad.

The significance of any change in the number of geese recorded in the surveyed tetrads between 1988–91 and 1999 and the population estimates had to be assessed using non-parametric techniques, as the data did not follow a normal distribution.

To assess whether there was a significant difference in the numbers of Canada and Greylag Geese recorded by the *Breeding Atlas* and in 1999, the differences in the counts made in individual tetrads within each stratum were calculated. The distribution of these changes was then sampled x_i times with replacement, where x_i is the number of tetrads in stratum i in the area of Britain covered by this survey, and the x_i changes summed. This was repeated 999 times with replacement to obtain a distribution of bootstrapped change values.

As there was no *a priori* reason for assuming that the goose populations had increased or decreased the test was two-tailed. Therefore for a change to be significantly different to zero, fewer than 25 of the sum of changes had to be greater than zero (signifying a decrease in population at $P < 0.05$) or smaller than zero (signifying an increase in population at $P < 0.05$).

The bootstrapping approach was also used to estimate the number of geese in each of the five sampled strata and in all five strata in the area of Britain sampled by the 1999 survey. In each instance the 95% confidence limits were based on the 24th and 975th ranked bootstrapped samples.

For comparative purposes, the number of geese present between 1988–91 in the area of Britain sampled by the 1999 survey was calculated making use of all of the *Breeding Atlas* data (Gibbons *et al*. 1993). This value was then compared to two estimates of the number of geese present in 1999 in the whole survey area. The first and more conservative estimate assumed that there had been no change in the three unsampled strata since 1988–91. The second estimate assumed that there had been the same proportional change in the three unsampled strata as in the five sampled strata. In both instances the estimates are indicative estimates that should only be cited with clear caveats.

All average per annum rates of population change were calculated using 1989 as the base year as most of the data used in the *Breeding Atlas* were collected by Gibbons *et al*. (1993) in 1988 and 1989 and hereafter 1988–91 is standardized to 1989.

RESULTS

In this section the range of values in parentheses following a population estimate are the bootstrapped 95% confidence limits of the population estimate. Estimates of population change and size in the five strata are reported. Estimates of population change and size for the whole of the area surveyed, including the three strata that were not sampled, are also reported,

but the observed rate of increase in the sampled strata makes it likely that the assumption of no change in the number of birds in the unsampled strata between 1989 and 1999 may be conservative.

Canada Goose

Between 1989 and 1999, Canada Goose numbers per tetrad decreased by 50% in 'rural lowland with much water cover' (P = 0.001), but increased by 246% in 'lowland with some water cover' (P = 0.001) and by 95% in 'high water, upland' (P = 0.001) (Table 3). 'High urban, high water, lowland' that held the highest densities of these geese in both time periods only increased by 3%. Even though this stratum held the highest densities of Canada Geese it only contributed 6.3% of the total population estimate because it only comprises 0.3% of the surface area of the area of Britain sampled as part of the 1999 survey. Overall the number of Canada Geese increased by 156% in the five sampled strata from 24 062 (20 971–27 509) to 61 632 (57 279–66 081), an average rate of increase of 9.9% per annum. In 1989 'lowland with some water cover' held the fourth highest density of Canada Geese, but by 1999 it held the second highest density of these birds (estimated by dividing the population point estimate in Table 3 by the percentage of Britain comprising that habitat). During the same period, 'rural lowland with much water cover' changed from being the habitat with the third highest density of Canada Geese to that with the fifth highest density.

Re-established Greylag Goose

Greylag Goose numbers per tetrad increased by 333% in 'lowland with some water cover' (P = 0.001). There was no significant change in the other strata (Table 4). Overall the number of Greylags increased by 214% in the five sampled strata from 8174 (6309–10 364) to 25693 (21794–29623) between 1988–91 and 1999, an average rate of increase of 12.1% per annum. 'Low urban, high water, lowland' held the highest densities of Greylags in both time periods (estimated from Table 4). By 1999, 'lowland with some water cover' that had held the fifth highest density of re-established Greylags in 1989 had the second highest density of these birds. During the same period, 'rural lowland with much water cover' changed from being the habitat with the third highest density of re-established Greylags to that with the fifth highest density. The relative change in importance of these two habitats was thus similar for Canada and Greylag Geese.

DISCUSSION

Canada Geese were already widespread and numerous

Table 3. The estimated number of Canada Geese in 1988–91 and in 1999 in the area of Britain sampled by the 1999 Goose Population Change Survey (see Fig. 1). The numbers in parentheses are the 95% confidence limits. The total estimate is based only on the five sampled strata.

Stratum	Habitat in GB (%)	*Breeding Atlas* 1988–91	1999 Survey	Change (%)
Highly urbanized lowland with much water cover	0.3	3 306 (1 839–5 317)	3 410 (2 275–4 871)	ns
Urbanized lowland with much water cover	0.5	3 606 (2 546–4 885)	3 865 (3 058–4 793)	ns
Rural lowland with much water cover	0.2	1 136 (517–1 966)	567 (306–911)	–50%*
Lowland with some water cover	6.3	15 067 (12 786–17 534)	52 072 (47 985–56 325)	246%*
Lowland with no water cover	75.7	18 760 (16 966–20 683)	–	–
Upland with much water cover	0.4	806 (344–1 404)	1 569 (1 102–2 099)	95%*
Upland with some water cover	1.2	866 (567–1 257)	–	–
Upland with no water cover	15.5	652 (488–845)	–	–
Estimate for eight strata		44 400 (40 716–48 364)	see text	–
Estimate for five sampled strata		24 062 (20 971–27 509)	61 632 (57 279–66 081)	156%

*P = 0.001.

Table 4. The estimated number of Greylag Geese in 1988–91 and in 1999 in the area of Britain sampled by the 1999 Goose Population Change Survey (see Fig. 1). The numbers in parentheses are the 95% confidence limits. The total estimate is based only on the five sampled strata.

Stratum	Habitat in GB (%)	Breeding Atlas 1988–91	1999 Survey	Change (%)
Highly urbanized lowland with much water cover	0.3	565 (111–1 229)	480 (297–696)	ns
Urbanized lowland with much water cover	0.5	1 957 (799–3 701)	2 792 (1 468–4 626)	ns
Rural lowland with much water cover	0.2	558 (294–909)	–	ns
Lowland with some water cover	6.3	4 829 (3 742–5 983)	20 924 (17 486–24 508)	333%*
Lowland with no water cover	75.7	3 996 (3 120–5 143)	–	–
Upland with much water cover	0.4	412 (112–850)	857 (487–1 289)	ns
Upland with some water cover	1.2	113 (49–210)	–	–
Upland with no water cover	15.5	69 (38–109)	–	–
Estimate for eight strata		12 351 (10 363–14 650)	see text	–
Estimate for five sampled strata		8174 (6309–10 364)	25 693 (21 794–29 623)	214%

*P = 0.001.

at the time of the last survey in 1991 when 46 700 adults were recorded (Stone *et al*. 1997). Between 1962 and 1976 their population had grown by an average of 8% per annum (Owen *et al*. 1986) and by an average of 8.3% per annum between 1976 and 1991 (Delany 1993). The growth and dispersal of Canada Geese was facilitated by the translocation of birds in the 1950s and 1960s (Kirby *et al*. 1999), ironically in an attempt to limit local population growth and agricultural damage.

In the area of Britain surveyed during 1999 there were 44 400 (40 716–48 364) Canada Geese in 1989 (estimated using data from Gibbons *et al*. 1993: Table 3). Making the conservative assumption that there had been no change in the Canada Goose population in the three unsampled strata, the population would be estimated to have increased to 81 931 in the area of Britain surveyed by 1999, a 6.3% per annum increase since 1989. Assuming that the proportional change in the Canada Goose population in the three unsampled strata was similar to the mean of that in the five sampled strata, the population would be estimated to be 113 725, a 9.9% per annum increase since 1989. Contrary to the evidence from the WeBS indices (Pollitt *et al*. 2000), the rate of growth of the Canada Goose population does not appear to have declined since 1962.

Between 1989 and 1999, average growth rates per annum of 13% in 'lowland with some water cover' and 7% in 'upland with much water cover' were recorded, and a decrease of 7% per annum in 'rural lowland with much water cover'. The two habitats where Canada Goose numbers increased had only held 6.5 and 6.8 Canada Geese per tetrad (Table 1). In two of the three habitats which had, and still have, the highest densities of Canada Geese in 1988–91 there was no evidence of a significant change in numbers; in the third, 'rural lowland with much water cover', Canada Goose numbers declined. Perhaps maximum densities may have been reached in these three high-density habitats and/or such control measures as egg-pricking may have been implemented. It is important that any future surveys sample 'lowland with some water cover' more extensively to increase the precision of the Canada Goose population in this habitat as it is estimated that in 1999 84% of the Canada Geese in the five sampled strata were in this habitat alone and that numbers there have risen dramatically (Table 3). Clearly, it is also important that the coverage of any future survey includes the strata that were not sampled by this survey.

Re-established Greylag Geese, descendents of 1000 birds released by wildfowling clubs in the late 1960s and early 1970s (Owen *et al*. 1986), were widespread in Great Britain at the time of the last survey in 1991 that recorded 13 100 adults (Delany 1992, Stone *et al*. 1997). Gibbons *et al*. (1993) estimated that there were

22 000 adults in Britain in 1988–91 but this included birds from the native North Scotland population estimated to comprise 1630 adults in 1986 (Paterson 1987). In the area surveyed during 1999, based on data from Gibbons *et al*. (1993), there were 12 351 (10 363–14 650) Greylag Geese in 1989 (Table 4). Making the conservative assumption that there had been no change in the Greylag Goose population in the three unsampled strata, the population would be estimated to be 29 875 in the area of Britain surveyed (a 9.2% per annum increase since 1989). This estimate is unlikely to be as accurate as that of the Canada Geese as the distribution of this species determined the survey design. Between 1989 and 1999, the population in the five sampled strata increased by 214%, an average rate of increase of 12.1% per annum. Between 1988–89 and 1998/99 the WeBS indices indicate a 100% increase for 'naturalized Greylags' (Pollitt *et al*. 2000), a figure that would appear to be an underestimate.

Between 1989 and 1999, in the five sampled strata the only significant change in Greylag population size occurred in 'lowland with some water cover' where the average rate of increase was of 16% per annum. The highest rate of Canada Goose increase was also recorded in this habitat and to increase the precision of the estimates of both species of goose it should be sampled extensively by the next survey. Both Greylags and Canada Geese can co-exist at a high density, both species experiencing high nesting success and considerable increases although gosling mortality can be higher amongst Canada Geese (Wright & Giles 1988). In 1999, it is estimated that 81% of the Greylag Geese in the five sampled strata were in this habitat (Table 4). Furthermore, and as also noted for Canada Geese, the relative importance of 'rural lowland with much water cover' measured in terms of goose density had declined.

The naturalized populations of Canada and Greylag Geese in Great Britain that are considered by some to add to the enjoyment of visiting wetlands can also be a nuisance. Neither species is globally endangered. Within the African–Eurasian Waterbird Agreement area, naturalized Canada Geese may have self-sustaining populations in 16 countries and Greylags in ten (Blair *et al*. 2000). Canada Geese have hybridized with 16 species of Anatidae and, being aggressive in nest defence, have killed ducks, Moorhen *Gallinula chloropus* and Coot *Fulica atra* (Lever 1987, Blair *et al*. 2000). Their aggressive defence of nests and young can also be intimidating to humans. This goose tends to dominate the wetlands where it is common and has also been found to be responsible for water eutrophication and ground erosion (Allan *et al*. 1995). It is also considered to be a potential vector of human and wildlife disease (Watola *et al*. 1996). It, like Greylags, can also be a serious agricultural pest (Owen *et al*. 1986, Lever 1987, Blair *et al*. 2000). Greylags have hybridized in captivity with 23 species of Anatidae (Lever 1987, Allan *et al*. 1995, Dawson & Evans 1996, Blair *et al*. 2000) and hybridization has also been frequently recorded in the wild (Delany 1993, Blair *et al*. 2000). Both species can thus be considered to be sources of genetic pollution.

Canada and Greylag Geese are a particular air traffic hazard as they are heavy, increasingly common and fly in small to large flocks. The vast majority of the jet engines on the world's aircraft are tested to withstand an impact with a bird weighing 4 lbs (1.78 kg) (Eschenfelder 2000), so birds of the size of Canada or Greylag Geese, weighing on average about 3.5 kg), pose a particular threat (Allan *et al*. 1999). Re-established and introduced geese, in particular, are often undisturbed by the presence of humans or noise and, being attracted to small water bodies, including holding ponds near airfields, they are often found near airports. Canada Geese have already been involved in several serious birdstrike incidents in the UK, and have caused over 300 birdstrikes in North America (Allan *et al.* 1999). These have included one fatal accident that resulted in the deaths of 24 people (Richardson & West 2000).

We therefore recommended that populations of Canada and re-introduced Greylag Geese be monitored at regular intervals to help assess their threat to native waterfowl, water quality, agriculture and aviation, and that appropriate management action be considered, at least at the local level, to alleviate problems (Allan *et al.* 1995). Any potential management action should be targeted more specifically at the Canada Goose, an exotic to the UK.

This paper describes a potentially useful method for rapidly assessing population change from a relatively small sampling effort, but unless all strata are surveyed, the primary function of the approach should not be to generate population estimates as these will be partly dependent on any numerical changes that have occurred in the unsampled areas. Any population estimates generated using this approach are only broadly indicative of any change that might have occurred and must be accompanied by relevant caveats relating to the assumptions made about any population change that may have occurred on the unsampled strata.

A full survey of introduced and re-established geese should aim to increase coverage of 'lowland with some water cover' as this holds over 80% of both species of geese and in particular to sample the habitats which were not covered by the 1999 Goose Population Change Survey. Such a survey would meet the urgent need to increase the precision of the population estimates presented in this paper and should at the same time assess the populations of other naturalized geese in Great Britain. It would also help determine the accuracy and precision of the WeBS indices for Canada and Greylag Geese.

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APPENDIX 1

1999 Goose Population Change Survey stratification details

Survey stratification

Classification of the degree of urbanization and degree of water cover was based on the Institute of Terrestrial Ecology remotely-sensed *Land Cover Map of Great Britain: one-kilometre summary data*, the last update of which was received in April 1997. The Land Cover Map is based on a pixel resolution of 25-m grid cell. Each record contains the percentage cover for each of 25 land cover classes for a 1-km Ordnance Survey grid square.

Urbanization was based on category 21, the 'Industrial, urban and any other developments, lacking permanent vegetation' defined as:

'The urban development category covers all developments which are large enough to completely fill individual pixels, to the exclusion of any significant quantities of permanent vegetation. It includes cities, large town centres, major industrial and commercial sites, major areas of concrete and tarmac, plus permanent bare ground associated with these developments, such as car-parks and tips.'

This information was used to derive three levels of urbanization for our tetrad stratification: 'highly urbanized' which is ≥ 5% urban, 'urbanized' which is (5% > urban > 0%) or 'rural' which is 0% urban.

Water cover was based on category 2, the 'Inland fresh waters and estuarine waters above the first bridging point or barrier' defined as:

'Inland water includes all mappable fresh waters and any estuarine waters which are excluded from category 1 (Sea / Estuary). The maps record only those areas that are water-covered on both winter and summer images. Thus, reservoirs with summer draw-down, or winter-flooded meadows are classified to the summer class (i.e. bare or grassland in these examples).'

This information was used to derive three levels of water cover for our tetrad stratification: 'much water cover' which is ≥ 5% water cover, 'some water cover' which is (5% > water cover > 0%) or 'no water cover' which is 0% water cover.

Land characteristics were based on the CEH LANDCLASS stratification (Benefield & Bunce 1982), which classifies each 1-km square into one of 32 landclass types. These were used to derive two classes of land characteristic for this survey (primarily upland and primarily lowland) as follows:

Land type classification used for 1999 Goose Population Change Survey	CEH landclass type
Lowland landclass types	1,2,3,4,5,6,7,8,9,10,11,12,13, 14,15,16,25,26,27
Upland landclass types	17,18,19,20,21,22,23,24,28, 29,30,31,32

For detailed descriptions of landclass types see Benefield and Bunce (1982). Landclass descriptions was used to derive two levels of land characteristics for our tetrad stratification: 'upland' >25% of tetrad (2–4 1-km^2 units) classified as upland landclass types and 'lowland' where ≤25% of tetrad (0–1 1-km^2 units) classified as upland landclass types.

Final stratification

The final stratification was derived by overlaying the urbanization, water cover and land characteristic classifications. The water cover and land characteristic classifications were completely cross-tabulated to give six categories. The urbanization classification was only cross-tabulated with one of the resulting six categories, high water lowland. Urbanization was very rare in the remaining five categories and a saturated three-way cross tabulation would have resulted in 18 categories many of which would contain no or very few tetrads. This resulted in eight strata (Table 1).