Numbers of Mute Swans *Cygnus olor* in Great Britain: results of the national census in 2002

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Abstract

In 2002, a census of Mute Swans *Cygnus olor* was carried out in Great Britain and the Isle of Man, to determine the size of the Mute Swan population during the breeding season and to distinguish between the numbers of breeding and non-breeding birds. Coverage of the whole country had been attempted previously, in 1955/56, 1978, 1983 and 1990, but was deemed impractical for this census. Instead, coverage of randomly selected 10-km squares was undertaken, which reduced the amount of fieldwork required and made it possible to calculate confidence intervals for the estimated population size. The population size was estimated at 31,700 birds, with 95% confidence levels of 28,600–35,200 birds. Separate estimates were made of the breeding or territorial component (6,150 pairs, with 95% confidence levels of 5,550–6,740 pairs) and non-breeding component (19,400 unpaired non-breeding individuals, 95% confidence levels of 16,700–22,200 birds). The Mute Swan population in Britain and the Isle of Man has thus increased by 23% over the period 1990–2002, a slower rate than during the 1980s. Coverage was achieved for all but 96 (92%) of the 1,100 10-km squares originally selected for surveying, a major improvement on previous censuses. This high level of coverage contributed to the accuracy of the population size estimate in 2002.

Key Words: *Cygnus olor*, Great Britain, breeding population, census.

The Mute Swan population in Great Britain is largely sedentary and is accepted as being discrete from the Irish and the continental European Mute Swan populations (Wetlands International 2006). In a recent assessment of the population status of birds in the UK (also including the Channel Islands and the Isle of Man), the species was moved from the 'Green' list to the 'Amber' list (Gregory *et al.* 2002) on the basis that 21.7% of the European-breeding population occurred in the UK. One of the criteria for inclusion on the Amber list is that a country holds ≥ 20% of the breeding birds in Europe. This has changed the conservation status of Mute Swans in Britain (and also in Northern Ireland) from favourable to being of medium conservation concern, and thus increased the need to monitor and conserve the species.

Three annual breeding bird surveys are currently undertaken in Britain: (1) the British Trust for Ornithology (BTO)/Joint Nature Conservation Committee (JNCC) Common Birds Census, (2) the BTO/JNCC/Royal Society for the Protection of Birds (RSPB) Breeding Bird Survey, and (3) the BTO Waterways Bird Survey. None of these are designed or intended, in terms of their methodology and coverage, for estimating the size of the Mute Swan population. Additionally, the BTO, Wildfowl & Wetlands Trust (WWT), RSPB and JNCC aim to monitor trends in numbers of non-breeding waterbirds in Britain and Northern Ireland through the Wetland Bird Survey (WeBS), for which counts are made mid-monthly from September–March inclusive, and this provides further information on the status of UK-breeding species for non-migratory populations. Mute Swan numbers in winter, as estimated by WeBS, remained fairly constant from the late 1960s through to the mid-1980s, since when a gradual and large increase in population size has occurred (Pollitt *et al.* 2003; Rowell & Spray 2004). Possible reasons for the increase are the reduced incidence of lead poisoning following the banning of the sale of lead fishing weights in 1987 (Kirby *et al.* 1994), and the increased survival and productivity of the species due to mild winters in recent years (Rowell & Spray 2004).

WeBS coverage is concentrated on key wetland sites such as large estuaries and gravel pits, with relatively little coverage of smaller wetlands and rivers. WeBS counts therefore do not record the entire winter population of the widely dispersed Mute Swan (Kirby *et al.* 1994). To address this issue, periodic national censuses have been undertaken during the breeding season, and these also provide information on the breeding and non-breeding components of the population. Further, they have provided useful information on Mute Swan distribution and habitat choice during the summer, which may differ markedly from the distribution observed during the winter months.

Prior to 2002, there have been four national censuses of Mute Swans in Britain, in 1955/56, 1978, 1983 and 1990, with an additional partial survey made in 1961 (Campbell 1960; Delany *et al.* 1992; Ogilvie 1981, 1986; Rawcliffe 1958). This paper describes the methods and results of the National Mute Swan Census undertaken in 2002. The key aims of the census were to

determine the size of the Mute Swan population and that of its constituent parts, namely the numbers of breeding or territorial pairs, and of unpaired non-breeding birds in the population.

Methods

Previous surveys

The large size, obvious white colouration and typical wetland haunts of the Mute Swan make it one of the easiest of the common bird species in Britain to count during the breeding season. Due to the highly territorial nature of Mute Swan pairs and their generally conspicuous nests, it is also possible to distinguish breeding and non-breeding components of the population. The 1955/56 Mute Swan census was one of the first to use 10-km squares as a recording unit for any bird survey in Britain (Delany *et al.* 1992). It relied on the excellent networks of regional representatives and fieldworkers (then known as the National Wildfowl Count network) maintained by the BTO, the Scottish Ornithologists' Club (SOC) and WWT, and attempted to gain complete coverage of Mute Swans in Britain. This was followed in 1961 by a partial aerial census of the swans in Britain, with counts verified by ground coverage of certain counties (Eltringham 1963). For the 1978 survey, the methodology was revised to include randomly selected sample squares in an attempt to avoid the biases of the previous censuses, for instance resulting from birdwatchers not wishing to survey areas where they suspected there were few birds (Greenwood *et al.* 1994).

In none of the surveys to date, however, was the distribution of coverage either random or systematic, making valid extrapolation difficult (Greenwood *et al.* 1994). For the censuses where the intention had been to cover the whole population, 100% coverage was never achieved, making it necessary to adjust population estimates by extrapolating from areas of good coverage to those not included in the survey. This relies on the coverage achieved being representative of the whole. Typically, however, counters concentrate on covering the more productive squares first, and such bias makes it difficult to extrapolate with any degree of confidence.

In order to address the bias in the event of gaps in coverage in the 1990 census, survey design in 1990 included an attempt to allocate the 10-km squares randomly. Each local organiser (roughly one per county) was given a list of squares in a random order. If full coverage was not possible, organisers were asked to ensure that the squares were covered in the order listed. Thus, because the order was random, it would still be possible to extrapolate to a total with confidence if only a proportion of all the squares were covered. Furthermore, so as not to discourage observers by asking them to visit squares where they knew that swans did not occur, local organisers were allowed to record 'probable blanks' for those squares where prior knowledge of the birds and habitats meant they were certain that there were no swans present. The random selection adopted in 1990 proved to be unpopular with many counters and coverage was achieved of only 85% of 10-km squares. Understandably, few counters

wished to visit 'poor' squares before 'good' ones, and in many areas squares high in the sequence of random squares were not covered (Greenwood *et al.* 1994). This bias meant that statistical confidence in the population estimate was not as good as originally envisaged. The use of statistically robust methods is becoming increasingly important for defending population size estimates, particularly where conflicting interests mean that the results may be challenged. Methods used for the Mute Swan censuses therefore were revised further in 2002, to ensure that confidence limits could be assigned to the total population size.

Survey design for the 2002 census

As for previous censuses, the 10-km square of the Ordnance Survey's national grid was used as the basic recording unit. The involvement of a new counter network, the UK Swan Study Group (SSG), which guaranteed coverage of a large number of squares by members of as part of their ongoing studies, was integral to the design of the survey. Elsewhere, the SOC and the WeBS network provided coverage. Due to the impracticalities of achieving complete coverage, count squares were selected at random to ensure that the number of swans recorded could be extrapolated to provide a total population size with known confidence limits. Moreover, the survey was stratified in order to improve the accuracy of the total whilst retaining counters' interest in the survey and thereby maximising participation. The latter was possible as each stratum was considered differently in the survey, enabling effort to be concentrated on the 'good' areas favoured by counters.

Using the results of the 1990 survey, the 10-km squares were grouped into four categories according to their density of Mute Swans: (1) squares with ≥ 50 birds, (2) squares with ≥ four pairs, (3) squares with 1–3 pairs or 0 birds in lowland habitats, and (4) squares identified as upland habitat that were expected to hold zero birds (i.e. generally unsuitable habitat for Mute Swans). The Centre for Ecology and Hydrology (CEH) "landclass" stratification was used to separate squares into lowland or upland habitats (see Appendix 1). Using these classifications as strata for a random stratified survey, bootstrapping was used to calculate the number of squares it would be necessary to cover in each stratum to achieve a population estimate with given confidence limits, based on the 1990 data. The assumption here was that the density distribution of birds in 1990 would broadly reflect the density distribution in 2002. Additionally, several groups planned complete coverage of large areas within their study regions (e.g. SSG members) and 10-km squares covered by this method were designated as pre-selected census squares and excluded from the random stratified sample. Once the number of 10-km squares required in each of the four strata had been determined, this number of squares was selected at random from all possible 10-km squares in the strata for Britain and the Isle of Man. Table 1 provides a breakdown of the numbers of 10-km squares in each stratum (see also Figure 1).

The census included all squares that held ≥ 50 birds in 1990, noting that in the 1990 census 14,000 of the 25,000 birds recorded

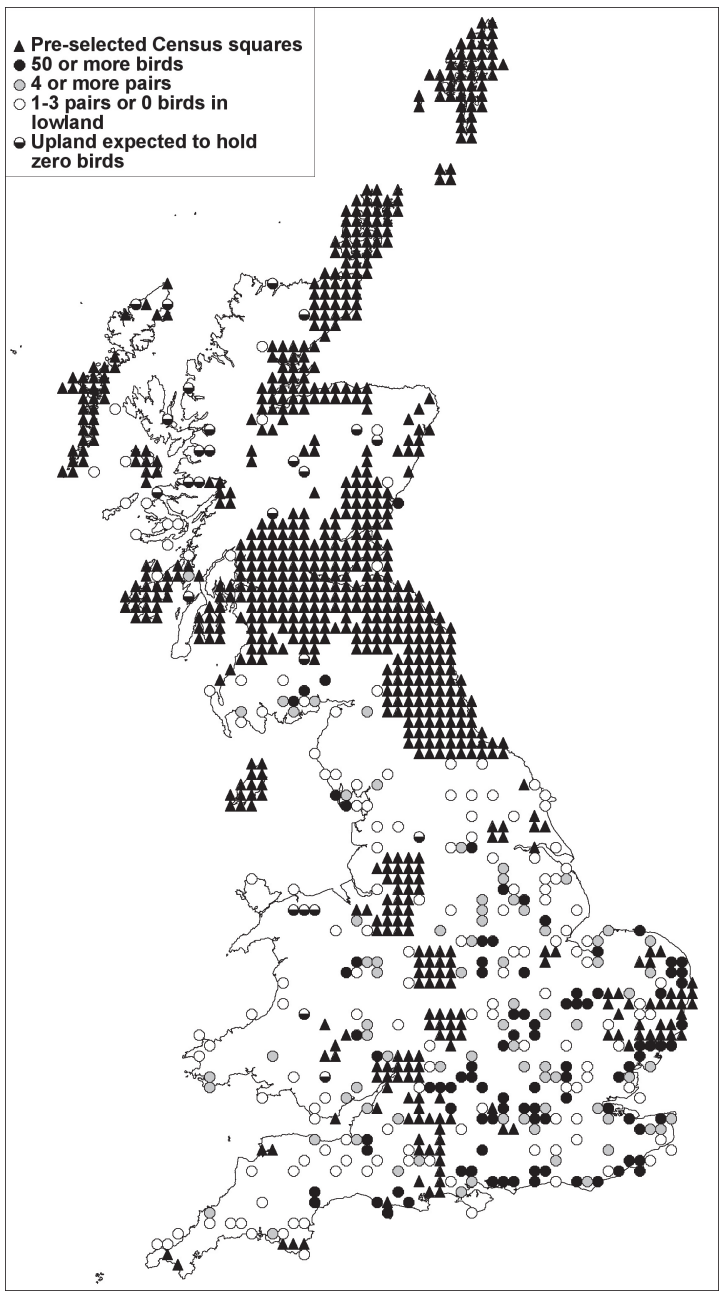
Table 1. Numbers of 10-km squares in each survey stratum for the census of Mute Swans in Britain and the Isle of Man in 2002.

Stratum (based on data from 1990 census results)	Total number of 10-km squares in Britain and the Isle of Man[a]	Percentage of squares in random sample for census	Number of 10-km sq. selected for coverage	Number of 10-km squares surveyed and used in the analysis			Additional squares covered[b]
				Breeding and territorial data	Non-breeding data	Total numbers data	
Squares with ≥ 50 birds	93 (94/95)	100%	93	77	74	74	
Squares with ≥ four pairs	213 (218)	35%	75	59	56	56	6
Squares with 1–3 pairs or 0 birds in lowland habitats	1,243 (1,256)	12%	150	115	114	114	72
Squares identified as upland that were expected to hold zero birds	497 (500)	5%	25	25	25	25	19
Pre-selected census squares that were excluded from the random stratified sampling process	757 (736/735)	100%	757	736	735	735	
Total	2,803	39%	1,100	1,012	1,004	1,004	97

[a] Because 21/22 squares scheduled for inclusion in the census were not eventually covered (for breeding/non-breeding data respectively), these squares were reassigned to the strata in which they would have occurred. The total number of squares for each of the strata therefore changed slightly for the analysis and these are given in parentheses, both for the total data and for the breeding/non-breeding data.

[b] Not included in the random sample of 10-km squares scheduled for coverage during the census, but count data for these squares were sent to local organisers.

Figure 1. Distribution of 10-km squares used in the Mute Swan census of Britain and the Isle of Man in 2002.



were found in just 125 of the 3,000 10-km squares surveyed. Through the stratified approach adopted, areas less favourable to Mute Swans and counters alike were also surveyed in 2002, but the number of these squares only formed a relatively small proportion of the total (17%, Table 1).

Fieldwork techniques

The field methods used in 2002 were similar to those used in previous Mute Swan surveys. From the list of 10-km squares selected for coverage, local organisers sought to allocate all squares in their region to volunteer counters. No specific instructions were provided to local organisers that gave priority to squares for surveying should coverage of all squares allocated not be possible. Counters were instructed to visit "all suitable habitat" for Mute Swans within the allocated squares, ideally between 1 April and 31 May 2002. However, by May, failed breeders may have deserted their territories to join non-breeding flocks, so counters were advised to attempt full coverage of non-breeding birds in April and in as short a time as possible to avoid double-counting. Complete coverage before the end of May was requested for all habitats suitable for breeding birds, but a slight extension to this period was considered acceptable for squares with extensive breeding habitat or for those in the northern part of the country where the Mute Swan breeding season is later.

On locating a pair of swans, counters were requested to check for signs of breeding by noting the presence of a nest or a brood of cygnets. Additional visits were only requested if confirmation was needed that a pair had bred. There was no requirement to check nests for the presence of eggs or to record the brood size. For unpaired non-breeding birds, counters were requested to record the size of the flock. In cases where the square (or part of the square) selected for coverage, was considered wholly unsuitable for swans, it was permissible for the relevant area to be recorded as a probable blank.

Observers provided details of localities, dates and numbers of birds present. For breeding birds, the total was broken down according to the breeding status of each pair, namely whether the pair was merely holding territory, at a nest, with cygnets, or appeared to be deserted/failed breeders. Observers also marked the position of all pairs or flocks on a blank grid of the 10-km square. The precise grid reference for each nest/pair or flock of swans was also requested.

Data processing

The analysis of unpaired non-breeders was restricted to counts made between 25 March and 15 May to minimise double-counting or missed birds, since non-breeders may be more mobile during spring and early summer than breeding birds and failed breeders may join non-breeding flocks at this time. Where multiple counts were made at a site, the one closest to 15 April was chosen. Records outside this period were included if they seemed likely to refer to birds that were not otherwise counted, for example because the site was isolated or because there were no other records of unpaired non-breeders for the square. The total numbers of such records and of those within seven days of the core count period were 170 (8.6% of the total number of unpaired non-breeding records used) and 46 (2.3%), respectively. Counts of

territorial and breeding pairs outside the April and May recording period were also used if it was deemed likely that they had not otherwise been included.

Data analysis

Numbers of swans present in each stratum were estimated by extrapolating the mean number of birds counted in the pre-selected 10-km squares to the total number of 10-km squares in the stratum. Total population size and the number of territorial and non-breeding birds within the population were then calculated by summing the estimates across strata. Confidence limits were calculated by bootstrap sampling of the data within each stratum. For each stratum, 999 samples of *n* squares were made with replacement, where *n* was the number of squares covered by the survey in the stratum. These squares also provided the data pool for replacement data. For each of the 999 bootstrap samples, the mean number of birds per 10-km square was calculated. These figures were then extrapolated to the total number of 10-km squares in Britain within each stratum, and confidence intervals were calculated as the 95-percentiles of the distribution of the simulated values. The number of birds in the pre-selected census squares was taken as the absolute estimate and no confidence limits were calculated. Population estimates and confidence intervals were calculated separately for (1) breeding and territorial pairs (hereinafter referred to as "territorial pairs"), (2) non-breeding individuals (excluding territorial pairs), and (3) total individuals, to provide estimates for subsets of the population and for the population as a whole.

Results

Coverage

During the census, 92% of the selected 10-km squares in Britain received full coverage or were considered to comprise habitat unsuitable for Mute Swans (Figure 2 and Table 1). The extent of coverage and unsuitable habitat varied between countries: 99.5%, 84.7% and 78.8% in Scotland, England and Wales, respectively. Seventeen regions received coverage of ≤ 50% of selected 10-km squares. A further 16 regions received coverage of 50–90% of selected 10-km squares, four received 90–99% and 76 received 100% coverage.

In addition to the 10-km squares selected across Britain, full coverage was achieved for a further 97 10-km squares, of which 84 were in Scotland and 13 were in England.

Estimated population in Britain

The Mute Swan population of Britain was estimated at 31,700 birds with 95% confidence levels of 28,600–35,200 birds (Table 2). This included 6,150 territorial pairs (95% confidence levels of 5,550–6,740 pairs) and 19,400 unpaired non-breeding individuals (95% confidence levels of 16,700–22,200 birds).

Abundance by 10-km square

Squares with high and moderate densities of Mute Swans

Forty-six 10-km squares had > 20 pairs or > 100 unpaired non-breeding Mute Swans during the census, here termed as high density areas. Although they account for a very small proportion of the 10-km squares in Britain (1.6%), these squares held an

Figure 2. Coverage achieved by the census of Mute Swans in Britain and the Isle of Man in 2002.

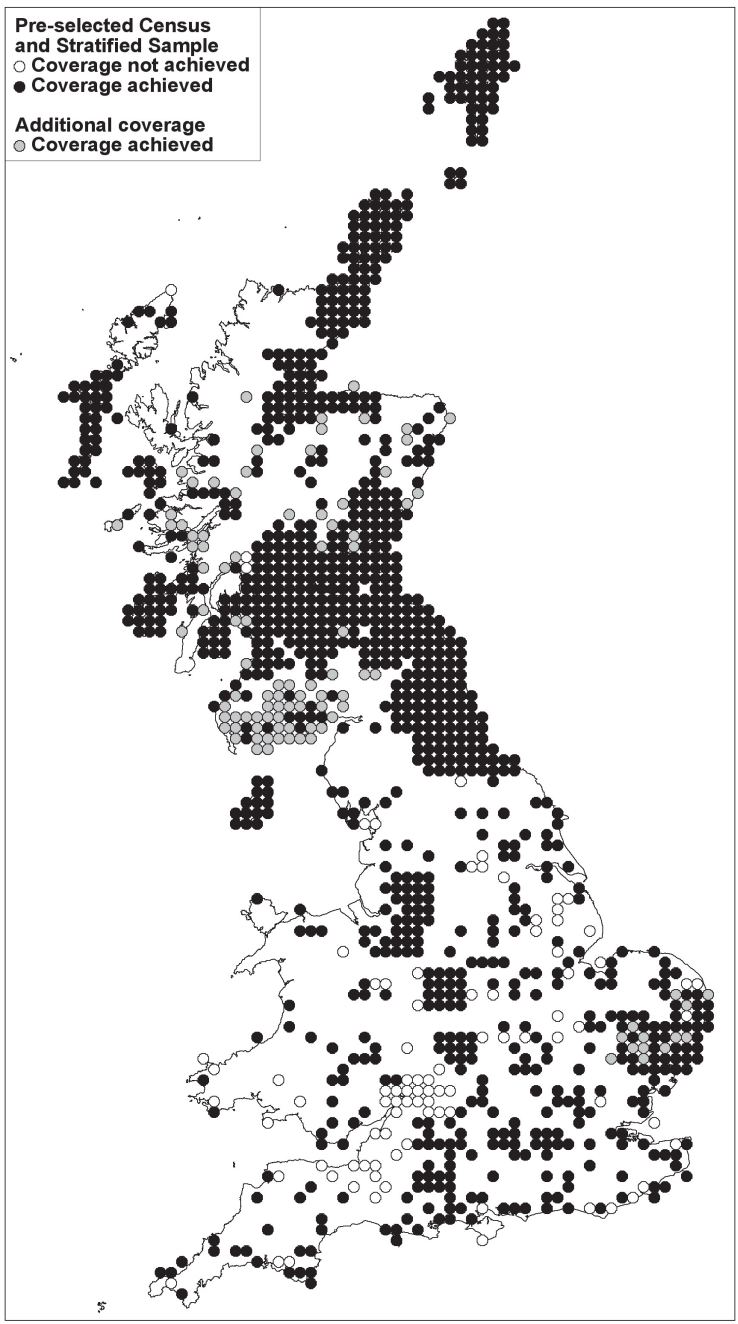


Table 2. Population estimates for Mute Swans in Britain and the Isle of Man in 2002, determined by extrapolation from the numbers counted in each stratum. Lower and upper 95% confidence limits are given in parentheses.

	Territorial pairs	Unpaired non-breeding individuals	Total
Pre-selected census squares	2,400	7,510	12,300
Squares with ≥ 50 birds	1,280 (986/1,690)	5,810 (4,560/7,280)	8,390 (6,600/10,400)
Squares with ≥ four pairs	1,070 (839/1,320)	3,780 (2,180/5,620)	5,930 (4,110/8,040)
Squares with 1–3 pairs of 0 birds in lowland habitat	1,350 (972/1,790)	2,270 (958/4,110)	4,980 (3,230/6,990)
Squares identified as upland that were expected to hold zero birds	40 (0/120)	0 (0/0)	80 (0/240)
Total	6,150 (5,550/6,740)	19,400 (16,700/22,200)	31,700 (28,600/35,200)

All estimates rounded as follows: >10,000 to nearest 100, >1,000 to nearest 10, >100 to nearest 1.

estimated 13% of the paired and 29% of the unpaired non-breeding birds in the population.

The most densely populated 10-km square contains the artificially-maintained colony at Abbotsbury in Dorset, where 146 nesting pairs and 260 unpaired non-breeders (total of 552 birds) were counted; elsewhere in the square a single pair was found nesting. The square with the second highest breeding density was in Orkney, with 125 pairs and 192 unpaired non-breeders (442 birds), the majority located on the Loch of Harray and the contiguous Loch of Stenness. An additional 13 pairs were found on those parts of the Loch of Harray within the adjacent 10-km square, so that 468 Mute Swans were recorded on the two lochs. Many pairs on the Loch of Harray have abandoned the territorial breeding system and nest colonially, this being the only site where such behaviour has been recorded in Britain under natural conditions (Meek 1993). As found by the 1990 census, the square with the next highest breeding density was in southeast Norfolk, which supported 48 pairs and 27 unpaired non-breeders, most within the Halvergate Marshes RSPB Reserve. A high breeding density was also found in the marshes further upstream in the Yare Valley.

Another important area in Britain for Mute Swans is the valley of the River Avon

and its tributary, the Wylye, in Wiltshire, Hampshire and Dorset. Here, five of six adjacent squares held > 20 pairs, the sixth supporting 18 pairs, with a cumulative total of 156 pairs and 875 unpaired non-breeding birds; about 2.6% of the British territorial population and 4.5% of the unpaired non-breeders.

The River Thames and associated man-made water bodies within two adjacent squares on the western fringes of London form another important complex with high densities of breeding and, in particular, non-breeding Mute Swans. Here, the cumulative total was 66 pairs and 360 unpaired non-breeding birds. Man-made water bodies, often gravel pits along river valleys, held most of the remaining high breeding densities of Mute Swan, these being predominately, but not exclusively, in the south and east of England. The notable exceptions were parts of Loch Bee, South Uist and the River Tweed in the Borders Region.

Although high densities of unpaired non-breeders were frequently found in or adjacent to squares with large numbers of paired birds, many were associated with large water bodies within areas of moderate densities of breeding Mute Swans. Most squares supporting high or moderate densities of breeding and non-breeding Mute Swans were either southeast of a line from the Severn Estuary to Flamborough Head, Yorkshire, or within the Forth-Clyde Valleys and northwards along the east coast lowlands into Angus. Amongst the notable exceptions were squares encompassing Kyle of Sutherland, Greater Manchester and the Northumberland coastal plain.

Squares with low densities of Mute Swans

The distribution of unoccupied squares was closely related to altitude and terrain, with the large upland blocks covered by the census in Scotland and northeast England being devoid of swans. Similarly, the squares to the south where swans were absent were areas of upland, moorland, chalk downland and extensive woodland; habitats not normally frequented by Mute Swans.

Discussion

Five comprehensive censuses of Mute Swans have now been carried out in Britain during the breeding season (Table 3), with a partial survey also undertaken in 1961 (Eltringham 1963). These suggest that the British Mute Swan population was largely stable between the 1950s and early 1980s, but that an increase observed in 1990 continued during that decade.

Results from a suite of national annual monitoring surveys, each encompassing a broad spectrum of species, also support the view that the number of Mute Swans in Britain has increased over the years. The three annual breeding bird surveys – the Common Birds Census, the Breeding Bird Survey and the Waterways Bird Survey – all indicate a steady population increase since the mid-1980s (Crick *et al.* 2004; Rowell & Spray 2004), though none of these surveys provides the level of precision of the national Mute Swan censuses. The Wetland Bird Survey (WeBS) Mute Swan index of wintering numbers shows a similar trend: numbers appear to be fairly constant from the late 1960s to the mid-1980s, followed by a large increase thereafter (Pollitt *et al.* 2003).

Table 3. Mute Swan population estimates from five breeding season surveys in Britain and the proportional change from previous census.

	1955/56	1978	1983	1990	2002[1]
England	15,600–17,300	13,340 –19%	14,800 +11%	20,000 +35%	–
Scotland	3,500–4,000	3,680 –2%	3,250 –12%	4,900 +51%	–
Wales	780	590 –24%	700 +19%	840 +20%	–
Total for Britain	19,900–21,600	17,600	18,750	25,750	31,700
% change between surveys		–15%	+7%	+37%	+23%

[1] The methods used in 2002 did not allow the calculation of estimates at a country level.

The WeBS data indicate a 33% increase in the wintering population between 1988/89–1992/93 and 1994/95–1998/99 (Kirby *et al.* 1994; Kershaw & Cranswick 2003). This compares with a 23% increase in the breeding population between 1990 and 2002 (Delany *et al.* 1992 and Table 3). However, this difference in the percentage increase becomes irrelevant when considering the statistical confidence of the estimates of the 2002 breeding season census.

A discrepancy exists between the most recent estimate of the number of Mute Swans in Britain in winter (37,500; Kershaw & Cranswick 2003) and that of the present 2002 breeding season census (31,700). Wintering numbers would be expected to be higher because of over-winter mortality prior to the start of the breeding season. Yet the results of the 2002 breeding season census are likely to be more accurate than the estimate derived from an extrapolation of the WeBS data. Since the proportion of wetlands covered by WeBS is not known, and because WeBS sites are not a random selection of wetlands, this extrapolation was based on several intensive surveys carried out in the early 1990s. These surveys attempted to cover all wetlands in a region and were used to calculate the proportion of birds missed by WeBS. For Mute Swans, these surveys indicated that WeBS missed a relatively large proportion of wintering birds, resulting in the estimate for the Mute Swan having a large extrapolated component (1.65; Kershaw & Cranswick 2003). As a result, it will be more susceptible to biases in the extrapolation methods. Additionally, since the Mute Swan population is known to have increased dramatically since the early 1990s, if the distribution of birds across sites has also changed (for example, if

numbers have increased more on WeBS sites compared with the smaller wetlands not counted by WeBS), extrapolated figures based on the 1990s' distribution of birds would be further susceptible to bias.

Reasons for the changes in the number of Mute Swans in Britain have been reviewed extensively elsewhere (e.g. Kirby *et al.* 1994). The national population increase from the mid-1980s is thought to be due primarily to the reduced incidence of lead poisoning (Rowell & Spray 2004). In Scotland, however, the incidence of lead poisoning has been much lower (Spray & Milne 1988), and the increase there may be due to milder winter weather (see later). In the late 1970s, poisoning from the ingestion of lead fishing weights was the largest single cause of death among Mute Swans in England (Sears & Hunt 1991). The incidence of lead poisoning declined substantially during the 1980s at least in some areas (c.f. Brown *et al.* 1992), due to a series of control measures regulating the use of lead weights (Sears & Hunt 1991; Owen 1992). However, despite the resultant sharp reduction in the number of swans dying or visibly suffering from lead poisoning and the corresponding increase in population size, a high percentage of birds in most flocks sampled recently still had elevated blood lead levels (Perrins *et al.* 2003). Such flocks were found on rivers that have been heavily used for coarse fishing in the past, and where lead fishing weights have persisted in the sediment of wetland habitats (Perrins *et al.* 2003).

Lead poisoning in Mute Swans that have ingested shotgun lead also occurs at some wetlands (Owen 1992; Spray & Milne 1988). Recently introduced control measures can, however, be expected to, and perhaps may already be, assisting in continuing the upward trend in the Mute Swan population in some areas. The use of lead shot in shotgun cartridges was banned over wetland areas in England and Wales in 1999 and 2001, respectively (Rowell & Spray 2004), and in Scotland in 2004 (Scottish Statutory Instrument 2004).

Whilst the recovery of the British Mute Swan population may in large part be attributed to the reduced incidence of lead poisoning, locally other factors may have had an equal or more important contribution to the observed changes. In an English Midlands study area, increased protection of nesting birds provided by members of the public and conservation organisations is considered a key factor in the reversal of the 1960s and 1970s decline, which had been execerbated in the area by nest vandalism and oil spills (Coleman *et al.* 2001). Furthermore, increased productivity of birds using the study area may have been helped by improvements in the water quality of the rivers and canals, following a reducation in pollution levels (Coleman *et al.* 2001), and this is also likely to be the case elsewhere in Britain (Rowell & Spray 2004). The increasing proportion of sand and gravel mineral workings restored to amenity value (DTLR 2002) may be beneficial to local Mute Swan populations, as this often creates new suitable breeding habitats (Rowell & Spray 2004). In Scotland, sand and gravel workings have had less influence on the increase in the numbers of pairs on still waters; here the creation of farm ponds and reservoirs has been more important (Brown & Brown 1999, 2005).

Mild winters throughout the 1990s are also considered to have been an important factor in facilitating the increase in Britain's Mute Swan population. These result in higher over-winter survival of Mute Swans, enabling pair bonds to remain intact and on territory (Coleman *et al.* 2001; Spray *et al.* 2002a). Furthermore, the adults are able to attain peak body condition, which in turn leads to the high reproductive output that follows mild winters (Esselink & Beekman 1991). This may be the key factor that has driven the Mute Swan population increase in Scotland, where lead poisoning has not been a significant cause of mortality and there is no ban on the use of lead fishing weights for coarse fishing (Delany *et al.* 1992; Spray & Milne 1988). Furthermore, in some areas of Scotland (e.g. the Montrose Basin and the Tweed Valley) and England (e.g. the Wylye Valley) foraging on agricultural crops outside the breeding season may have enhanced over-winter survival. Although a study of swan distribution in relation to habitat in winter 1990–91 found no more than 7% of Mute Swans on agricultural land (arable crops and grassland; Rees *et al.* 1997), the use of farmland has increased considerably since then, and the incidence is far higher in certain local areas; over 90% of swans in the Tweed Valley and over 80% of those in the Wylye Valley fed on agricultural land (Spray *et al.* 2002b; Trump *et al.* 1994). This has been accompanied by increasing concern about the potential for swans to cause damage to agricultural crops (Chisholm & Spray 2002). Indeed, in northeast Scotland the planting of sacrificial crops has been trialled, combined with scaring, to concentrate birds away from other oilseed rape fields (Spray *et al.* 2002b).

Though the Mute Swan population in Britain continued to increase during the 1990s, the rate of change was less than between the two previous censuses. Greenwood *et al.* (1994) used a new method of interpreting data from the 1978, 1983 and 1990 censuses to provide national population estimates of breeding birds (Table 4). When using these estimates together with the estimate for breeding birds from the present census, the overall rate of increase has been in steady decline (Table 4). Amongst several long-term local studies undertaken by Swan Study Group members, there is further evidence indicating a reduction in the growth rate of the Mute Swan population. For example, in an English Midlands study, the local Mute Swan population seems to have stabilised, or even declined slightly, since 1997, in both its breeding and non-breeding

Table 4. Numbers of territorial Mute Swan pairs (including breeding pairs) in Britain derived from the 1978, 1983, 1990 and 2002 censuses. The 1978, 1983 and 1990 estimates are from Greenwood *et al.* (1994).

	1978	**1983**	**1990**	**2002**
Total pairs in Britain	3,556	4,412	5,299	6,150
Proportional increase from the previous census		24%	20%	16%

components (Coleman *et al.* 2001). Elsewhere, underlying a continual growth in the Mute Swan population in Lothian, Scotland, between 1978 and 1998, there has been a reduction in the proportion of those birds holding territory since the late 1990s (Brown & Brown 1999). Nationally, between 1990 and 2002, the proportional increases of the two components of the population, territorial pairs and unpaired non-breeding, were 19.6% and 26%, respectively. A greater increase in the numbers of non-breeding birds, as shown by these data, would be expected if, for example, the availability of breeding territories was becoming a limiting factor. Whether this is occurring or whether other factors are regulating the apparent differential rate of change of the different population components is a key area for the focus of future research. In helping to achieve a better understanding of the changes being monitored, the opportunity to involve the many interested swan fieldworkers countrywide is highly recommended.

The 2002 census was designed only to provide statistically valid estimates of the Mute Swans at a Great Britain level. No quantification of any changes at a regional level can be drawn from the present survey's results. If regional trends in the Mute Swan population were available to consider, there would be difficulties in interpreting and comparing change, because the extent to which the growth and activity of Swan Rescue Centres has influenced some local populations has yet to be quantified. With some centres handling up to 400 birds a year, and as many as 5,500 passing through English and Welsh centres annually (Spray *et al.* 2002a), over 10% of birds in the British population may have had their survival enhanced by these centres each year.

The atlas of birds breeding in Britain and Ireland in 1988–1991 (Gibbons *et al.* 1993) showed the Mute Swan to be a widespread but predominantly a lowland species in Britain; it rarely occurs at altitudes of above 300 m (Ogilvie & Delany 1993). Although absent from many northerly and westerly areas, where high ground predominates, Mute Swans are abundant in southern parts of the Outer Hebrides and also on Orkney. This census was not designed to map the distribution of Mute Swan in Britain. However, for those areas surveyed, the pattern of distribution conformed to that described previously. Areas with high densities of Mute Swan in 2002 similarly were consistent with those reported more than 10 years ago for the breeding birds' atlas (Ogilvie & Delany 1993).

The success in the coverage requested and attained for this census through using a random stratified sample approach is manifest in the accuracy of the population estimate. This is a major advance upon previous censuses where bias generated from incomplete coverage has provided population estimates with low statistical confidence. It is recommended that the same or a similar methodological approach be adopted for future surveys. However, it would also be beneficial to the understanding of the underlying processes driving changes in the population if the magnitude of any change at a regional level could also be assessed by the census.

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Appendix 1

The Centre for Ecology and Hydrology (CEH) "landclass" stratification (Benefield & Bunce 1982) classifies each 1-km square into one of 32 land class types. These landclass descriptions allow, through derivation, each 1-km square to be categorised as either 'upland' or 'lowland' habitat (see below). For detailed descriptions of landclass types see Benefield and Bunce (1982). This was used in the present study for the 10-km stratification, categorising each square as either (1) 'upland' where there was >25% of its tetrads classified as upland landclass types or (2) 'lowland' where ≤ 25% of tetrads are classified as upland landclass types.

Land type classification used for 2002 Mute Swan Census	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