Population size and breeding success of Icelandic Whooper Swans *Cygnus cygnus*: results of the 2010 international census

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Abstract

Trends in total population size and mid-winter distribution have been determined for the Icelandic Whooper Swan population through coordinated international censuses, undertaken in January across its wintering range in Britain, Ireland and Iceland, at *c.* 5-yearly intervals from 1986 onwards. A total of 29,232 swans recorded during the sixth international census in January 2010 represented an increase of 11% on the previous census in 2005 and is the highest census total to date. Overall, 35.8% of the population (10,452 swans) was recorded in the Republic of Ireland, 30.8% (8,999) in England, 15.8% (4,616) in Northern Ireland, 9.1% (2,659) in Scotland and 7.8% (2,278) in Iceland, with the combined total in Wales and the Isle of Man accounting for < 1% of birds counted. There was a significant increase across censuses (1986–2010) in the proportion of birds wintering in England, in comparison with the rest of the range, whereas the Republic of Ireland and Scotland saw a significant decline. This suggests an overall shift to the southeast in the swans' winter distribution, though a prolonged period of cold, snowy weather prior to the January 2010 census may have resulted in more birds moving south from Scotland, or potentially from mainland Europe, in this year. The majority of Whooper Swans in Ireland were recorded on pasture in 2010, whilst in Britain they were seen mainly on arable land. Although the frozen conditions in 2010 are likely to have influenced habitat choice, there has been a general increase in the use of arable land by Whooper Swans since 1995.

Key words: distribution, habitat, trends in numbers, Icelandic population, international census, productivity, Whooper Swans.

The Whooper Swan *Cygnus cygnus* has a widespread breeding distribution in the northern Palaearctic, extending from Iceland and northern Scandinavia, across Russia, to the Pacific coast (Brazil 2003; Rees *et al.* 2002). The Icelandic-breeding population of Whooper Swan is one of five populations described for this species (Brazil 2003; Wetlands International 2006); ringing and count programmes indicate that most of the Icelandic Whooper Swans migrate to winter in Britain and Ireland, with a small proportion (500–1,300 individuals) remaining to overwinter in Iceland (Black & Rees 1984; Gardarsson 1991; Rees *et al.* 2002). Satellite tracking studies have demonstrated that the swans may undertake the 1,400 km overseas flight between Ireland and Iceland either direct or via Scotland (Rees 2009), but there is a minimum 800 km overseas flight between Britain and Iceland, and the swans are vulnerable to being blown off course or unable to make landfall if they encounter strong head or side winds during the flight (Pennycuick *et al.* 1996; Rees 2009). In the early part of the 20th century, the swans fed mainly on aquatic vegetation during the winter months, but use of agricultural land became more frequent from the 1960s onwards, at a time of agricultural intensification in Britain and Ireland. The habitat switch on to cropped land (arable and agriculturally-improved pasture), together with an increase in the numbers of birds wintering in Britain and Ireland during the second half of the 20th century, has resulted in some conflict with agricultural interests, particularly in relation to re-seeded grasslands, winter cereals, root crops and oil seed rape (Robinson *et al.* 2004; Chisholm & Spray 2002).

Whooper Swans have been monitored annually in Britain since the 1950s, largely through the Wetland Bird Survey (WeBS; formerly the National Wildfowl Counts), undertaken each month during the winter, and extended to Northern Ireland in 1986. Similarly, the Irish Wetland Bird Survey (I-WeBS) has monitored waterbird numbers and distribution in the Republic of Ireland since winter 1994/95. Additional count data on Whooper Swans in Ireland have been collected by the Irish Whooper Swan Study Group (IWSSG) since the early 1990s. Numbers of Whooper Swans wintering in accessible areas of Iceland have been recorded as part of the annual winter bird census coordinated by the Icelandic Institute of Natural History (IINH) each year since 1952. Although coverage for WeBS and I-WeBS includes many wetland sites in Britain and Ireland, the daily dispersal of Whooper Swans away from wetland roost sites and their tendency to feed at temporary wetlands and in non-wetland (generally farmland) habitats means these surveys miss a substantial proportion of the population. Likewise, counts undertaken annually in Iceland may miss some overwintering birds because the swans are rather scattered at this time and accessing some areas by foot or car can be difficult in harsh weather conditions. Coordinated species-specific surveys that include these areas are, therefore, required to provide accurate estimates of population size, which are used to identify sites of national and international importance for the species, with regular counts of ≥ 1% of

the total population being one of the criteria used for designating sites Special Protection Areas under the EU Birds Directive. Extensive coordinated surveys are also important for verifying trends in numbers identified by the national count programmes, and for describing any changes in feeding habitat as habitat is not usually recorded in the WeBS and I-WeBS programmes.

An international census of the Icelandic-breeding Whooper Swan population has been carried out in mid-January at *c.* 5-year intervals since 1986, as part of a wider census of wintering migratory swans in Europe, coordinated by the IUCN-SSC/Wetlands International Swan Specialist Group. Results from the early censuses show fluctuating numbers, with totals of 16,742, 18,035 and 15,842 individuals recorded in 1986, 1991 and 1995, respectively (Salmon & Black 1986; Kirby *et al.* 1992; Cranswick *et al.* 1997). More recent censuses have shown a growth in the population, with totals of 20,856 Whooper Swans in 2000 and 26,366 recorded in 2005 (Cranswick *et al.* 2002, Worden *et al.* 2009). As the number of Icelandic Whooper Swans has increased there has been a noticeable shift in the distribution of birds across countries, with an increasing proportion located in England (Worden *et al.* 2009). Additionally, there are indications that birds are moving to southern locations earlier in the winter than has previously been noted (Spray 2007). The number of swans remaining to overwinter in Iceland has also increased, although as a proportion of the total population there has been only small variation between censuses.

This paper presents the results of the sixth international census of Whooper Swans in Britain, Ireland and Iceland, which took place in January 2010. It aims to describe trends in the numbers and mid-winter distribution of the Icelandic Whooper Swan population from the first international census (in 1986) onwards and also to determine regional variation in the percentage of juveniles recorded. The habitats on which the birds were observed during each of the censuses since 1995 are analysed to assess any major changes in habitat use by the swans over time.

Methods

The 2010 international census of Icelandic Whooper Swans was coordinated by the Wildfowl & Wetlands Trust (WWT) and followed the methods used in previous years, as well as covering the same count areas (details in Worden *et al.* 2009). The census in Britain was organised by WWT, in Ireland by BirdWatch Ireland and the IWSSG, and in Iceland by Ólafur Einarsson and the IINH. Counts were undertaken by a network of volunteers (including WeBS and I-WeBS counters and IWSSG members) and professional staff.

The main census dates of 16–17 January 2010 were chosen to coincide with the WeBS and I-WeBS counts in that month. In addition, counters were asked to visit sites known to have held, currently hold or may potentially be suitable for Whooper Swans but are not regularly covered by these other surveys. An aerial survey was undertaken in Ireland on 22 January to ensure complete coverage of areas with limited accessibility: the Rivers Suck, Brosna

and Shannon Callows (south of Athlone), Lough Derg and the Shannon and Fergus Estuary.

In Iceland, data were collected mainly through the annual winter bird census with ground counts undertaken in the northeast, southeast, southwest and west of the country between 26 December 2009 and 12 February 2010. An aerial survey of the southern lowlands, not covered by the winter bird census, was undertaken on 30 January 2010. The broad range of dates is considered acceptable as only small numbers of birds are recorded and there is probably little movement between sites in Iceland during midwinter.

Submitted data were checked to identify duplicate counts, due to sites being surveyed more than once or where birds were believed to have moved between adjacent sites. Where duplicate counts occurred, the criteria used to select data for inclusion in the analysis included the following: proximity to the census weekend, coordination with adjacent sites, and whether the count was said by the observer to be most representative of the number present at the site. Any counts considered to be duplicates were excluded from the census totals. For sites where no count was carried out on the census weekend, data were included for a week either side but only if it was deemed unlikely that birds may have moved in from other sites. Only in exceptional circumstances were counts from outside this time period included and only then if the risk of double counting was thought to be minimal.

Counts and age assessment data were grouped by country for analysis, namely: Iceland, Northern Ireland, the Republic of Ireland, Scotland, England/Isle of Man (only small numbers occurred on the Isle of Man so these data were combined with England) and Wales. This grouping helps facilitate comparison with earlier studies and also provides a north/south and east/west divide for assessing distribution. For some analysis of breeding success, countries were further divided into regions, definitions of which are given in Appendix 1 in Worden *et al.* (2009).

Chi-squared tests were used to determine whether there was any significant difference in the proportion of swans and number of flocks recorded across countries between the 2005 and 2010 censuses, and in the frequency of brood sizes recorded in each country compared to the rest of the range. Productivity data (*i.e.* the proportion of cygnets recorded in wintering flocks, arcsine transformed) were not normally distributed (Shapiro-Wilk test: $W = 0.7643$, $P < 0.001$); non-parametric Kruskal-Wallis tests therefore were used to assess differences between countries and regions in the proportion of young birds, and also in the brood sizes recorded. Mann-Whitney tests assessed differences in flock size within countries between the 2005 and 2010 censuses. Generalised linear models (GLMs), specifying a Poisson error distribution with log link function, investigated whether the total number of swans counted in each country during each of the censuses varied significantly between countries and across years. The dispersion parameter was not fixed, to control for overdispersion in the count data (Crawley 2002). Country (included as a factor), year

(included as a variate with 1986 = year 1, to test for trends over time) and the quadratic function of year (*i.e.* year^2, to test for any curvilinearity in population trends) were included as explanatory variables in the initial maximal model. Two-way interaction terms were also tested for significant variables. Non-significant variables were omitted sequentially from the GLM, the least significant variable being omitted first, so that the final model was parsimonious. Linear regression analysis of the proportion of birds recorded in each country (arcsine transformed) in the international censuses from 1986 onwards further tested for trends in the mid-winter distribution of Whooper Swans over time.

Results

Coverage

The weekend of the census followed a period of very cold weather in Britain and Ireland, with the majority of the region covered in snow and many waterbodies completely frozen. Although a thaw had set in by the time the census was undertaken, some areas were still difficult to access.

In Britain, 64% of the counts (where swans were recorded, n = 247) were conducted on the core weekend, with a further 30% within three days either side. All counts were carried out between 12 and 24 January, with the exception of one at The Wash, Lincolnshire/Norfolk which was undertaken on 3 January. The counts carried out late in January were mainly in the Scottish Highlands where conditions were too poor to undertake surveys on the core weekend.

In Northern Ireland, counts were undertaken between 15 and 27 January, with 33% (where swans were recorded, n = 102) carried out on the core weekend and a further 45% within three days either side. Those sites covered outside this period included Upper Lough Erne, which could not be counted on the core weekend due to fog. In the Republic of Ireland, 62% of counts (where swans were recorded, n = 284) were conducted on the core weekend, whilst 23% were carried out within three days either side. The remaining counts were undertaken outside this period, but between 10 and 31 January.

Counts in Iceland were carried out between 26 December and 12 February. Coverage was good for most regions with the exception of the northeast where, based on numbers from previous years, it was thought that 20–50 swans may have been missed. It is also possible that 10–20 birds may have been missed in western areas, although coverage there was considered to be fairly good. An aerial survey of the southern lowlands did not cover an area between Skógar and Meðalland where up to 50 swans have been located in previous censuses.

Numbers and distribution

A total of 29,232 Whooper Swans was recorded in 755 flocks in Britain, Ireland and Iceland during the January 2010 census (Table 1), a 10.9% increase on the 26,366 swans recorded in 2005 (Fig. 1, Table 2). All countries except Scotland saw an increase in total numbers, with the rate of increase in Northern Ireland and the Republic of Ireland being less than that of the entire population (Table 2). Over 40% of the

Table 1. Numbers of Whooper Swans recorded in Iceland, Ireland and Britain during the international census in January 2010.

	Number of swans	Number of flocks
Iceland		
South	1,222	88
Southwest	654	20
Northeast	327	10
West	50	3
Southeast	25	1
Total	**2,278**	**122**
Northern Ireland		
Londonderry	1,673	29
Fermanagh	1,020	27
Down	548	10
Antrim	520	13
Armagh	508	13
Tyrone	347	10
Total	**4,616**	**102**
Republic of Ireland		
Galway	1,104	35
Mayo	966	33
Cavan	865	29
Donegal	854	18
Roscommon	774	24
Offaly	650	9
Wexford	641	5
Clare	639	17
Westmeath	566	7
Kerry	537	6
Waterford	485	11
Meath	416	7
Monaghan	414	23
Tipperary	276	8
Cork	215	10
Longford	210	8
Limerick	194	2
Sligo	186	9
Laois	151	2
Leitrim	130	12
Kildare	112	5
Wicklow	41	2
Louth	25	1
Kilkenny	1	1
Total	**10,452**	**284**
Isle of Man	**27**	**1**
England		
Cambridgeshire	4,546	27
Lancashire	2,405	14
Norfolk	1,426	11
Cumbria	313	10
Northumberland	100	5
Cheshire	71	2
Humberside	36	3
Lincolnshire	22	1
South Yorkshire	21	2
West Yorkshire	20	1
Shropshire	10	2
Gloucestershire	8	1
Bedfordshire	6	3
Kent	3	2
Devon	3	2
Somerset	2	1
Northamptonshire	2	2
Cornwall	2	1
Suffolk	1	1
Essex	1	1
Leicestershire	1	1
Total	**8,999**	**93**
Scotland		
Dumfries & Galloway	940	21
Highland	393	22
Strathclyde	265	23
Tayside	253	12
Orkney	166	11
Fife	139	3
Shetland	136	28
Lothians	122	2
Western Isles	118	16
Borders	66	2
Grampian	51	2
Central	10	3
Total	**2,659**	**145**
Wales		
Gwynedd	113	3
Dyfed	45	2
Clwyd	23	2
Powys	20	1
Total	**201**	**8**
Overall total	**29,232**	**755**

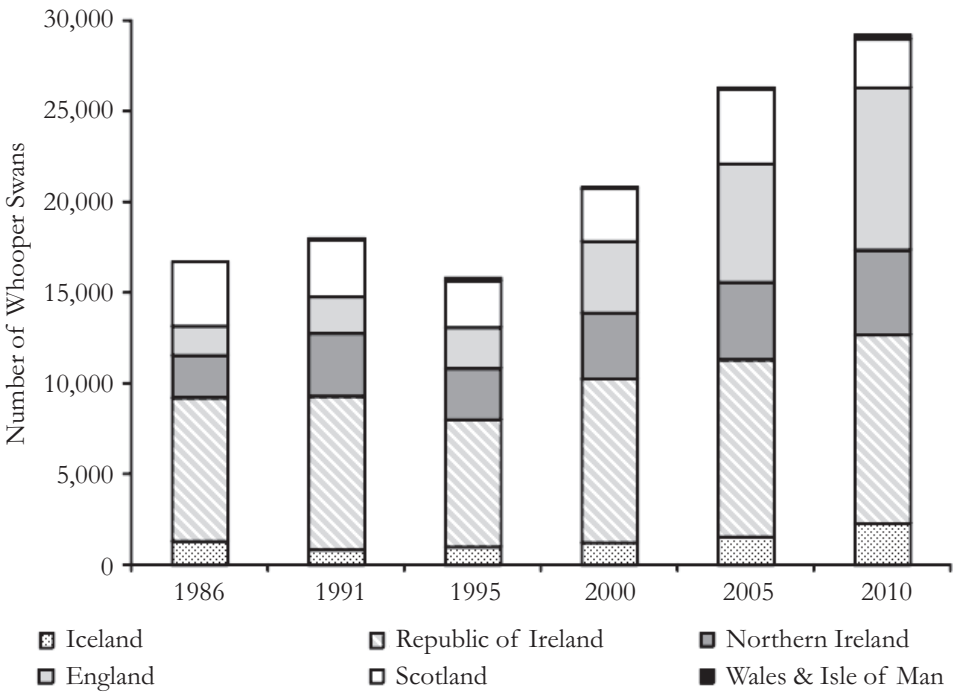


Figure 1. . Number of Whooper Swans recorded during the international censuses of the Icelandic-breeding populations from 1986–2010 inclusive.

swans were located in Britain, 51.5% in Ireland and 7.8% in Iceland. There was a significant shift in the distribution of swans across countries between 2005 and 2010 (χ^2_6 = 799.5, $P < 0.001$) (Table 2). The number of swans counted varied significantly both by country and over time (GLM: $F_{24,4}$ = 9.30, $P < 0.001$ for country; $F_{24,1}$ = 9.25, $P < 0.01$ for year[2]). There was a significant increase in the proportion of the population recorded in England/Wales/Isle of Man across all censuses (1986 to 2010) (linear regression: $F_{5,1}$ = 143.41, t = 11.98, $P < 0.001$), and a significant decrease in Scotland ($F_{5,1}$ = 19.23, t = –4.39, $P < 0.05$) and the Republic of Ireland ($F_{5,1}$ = 45.78, t = –6.77, $P < 0.01$), with the proportion recorded in Northern Ireland and in Iceland remaining relatively stable over this period ($F_{5,1}$ = 0, t = –0.03 and $F_{5,1}$ = 0.1, t = 0.32, respectively, n.s. in each case; Fig. 2).

In Britain, the majority of birds (30.8% of the overall population) were recorded in England; the proportion wintering there being notably higher than during the 2005 census (24.6%; Table 2 & Fig. 2). Swans were distributed from Northumberland to Devon, with the largest concentrations occurring at the Ouse Washes, Norfolk/Cambridgeshire, and Martin Mere, Lancashire, where flocks totalled 5,632 and

Table 2. Total numbers of Whooper Swans recorded in Iceland, Ireland and Britain during the international censuses in January 2005 and 2010, and the percentage change between the 2005 and 2010 censuses. Total numbers in 2010 were compared with 2005 using Chi-square tests with d.f. = 1 for comparison of each country with the rest of the range, and d.f. = 6 for overall comparison.

	Number of birds in 2005	Number of birds in 2010	% change in number of birds	Comparison of total numbers	
				χ^2	*P*
Iceland	1,556	2,278	46.4	77.2	<0.001
Northern Ireland	4,331	4,616	6.6	4.1	<0.05
Republic of Ireland	9,748	10,452	7.2	8.9	<0.005
England	6,480	8,999	39.3	265.9	<0.001
Scotland	4,142	2,659	–38.5	564.7	<0.001
Wales	94	201	113.8	28.8	<0.001
Isle of Man	15	27	80.0	2.3	n.s.
Overall	**26,366**	**29,232**	**10.9**	**799.5**	**<0.001**

2,052, respectively (Table 1, Fig. 3a). Whooper Swans were recorded at a further 45 sites, where total numbers ranged from a single bird to 337. Ten counties, which held birds in 2005 recorded no birds in 2010, although these accounted for < 2% of the previous census total for England and consisted mainly of flocks of one or two birds. Five counties recorded birds in 2010 where none were seen in 2005 but these contributed < 1% of the 2010 total.

Scotland held 9.1% of the population, a notably smaller proportion than in 2005 (15.7%; Table 2 & Fig. 2), and swans were located at 139 sites within Scotland, distributed across the country from the Shetland Isles to Dumfries & Galloway (Table 1, Fig. 2). Total numbers ranged from one individual to 271, with the largest flocks observed in Strathclyde, Highland and Dumfries & Galloway. Except for Dumfries & Galloway, all counties held considerably fewer birds compared with the numbers recorded in 2005.

Wales and the Isle of Man each held < 1% of the total population (Tables 1 & 2). Seven sites were found to have Whooper Swans in Wales, where 8–72 swans were counted, and one flock was seen on the Isle of Man (Fig. 3a).

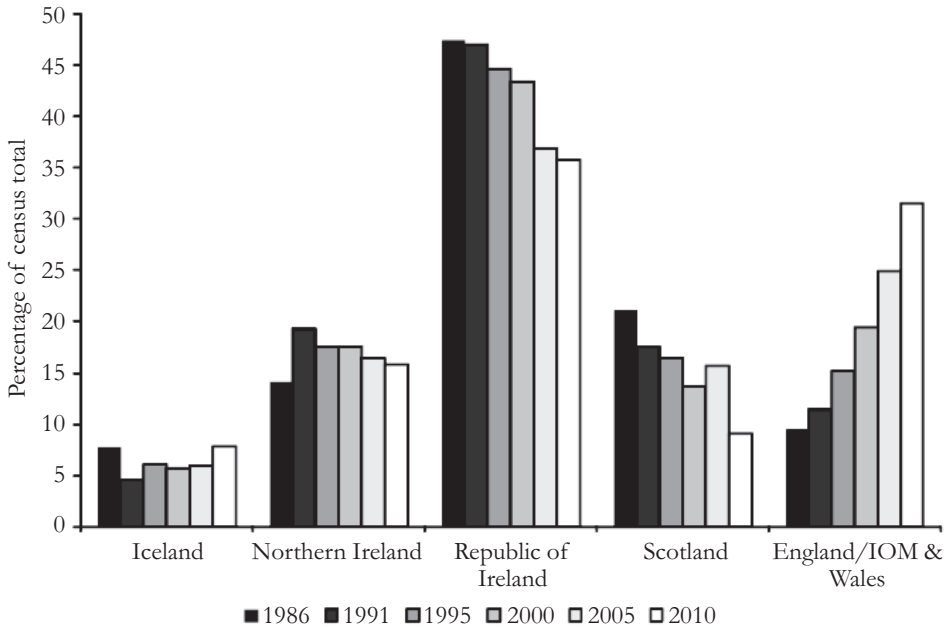
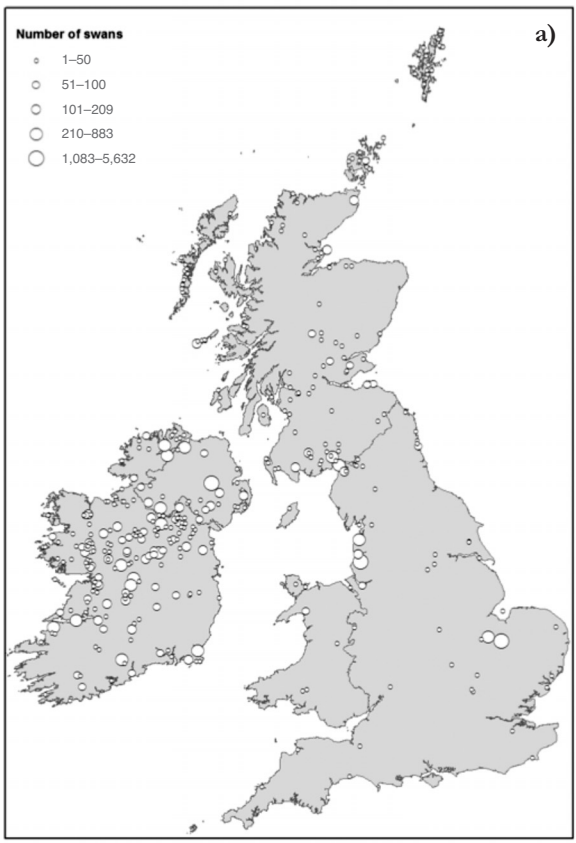


Figure 2. Changes in the distribution of Whooper Swans across Iceland, Ireland and Britain during the international censuses of 1986–2010. Note: Wales and Isle of Man have been combined with England as each only contributes <1% to the census totals each year.

In Ireland, 35.7% of the population was recorded in the Republic of Ireland whilst 15.8% were seen in Northern Ireland, a slight reduction on the proportion observed in each country during 2005 (37% and 16.4%, respectively) (Table 2, Fig. 2). Whooper Swans were recorded in all counties except Carlow and Dublin (Table 1). Londonderry, Fermanagh and Galway held the highest proportions of birds; Louth and Kilkenny had just 25 and one swan respectively, but no swans were recorded in these two counties during the previous census. Loughs Neagh & Beg (Antrim/Londonderry/Tyrone/Armagh/Down), Lough Foyle (Londonderry/Donegal) and Upper Lough Erne (Fermanagh) held the highest numbers, with 1,803, 883 and 799 individuals, respectively (Fig. 3a). A further 210 sites in Ireland held birds, with total numbers ranging from one to 506 swans.

A slightly higher proportion of the population overwintered in Iceland compared with 2005 (Fig. 2). Swans were predominantly seen in the south, southwest and northeast of the country (Table 1, Fig. 3b). The largest concentrations were located at Hólsá (290), Þykkvabæjarvatn (182), and Landbrot and Meðalland (131) in the south, and at Breiðan og Álar, Lake Mývatn (182) in the northeast. Elsewhere, birds were distributed in smaller flocks, ranging from one to 86 individuals. Whooper Swans were often observed along stretches of river or coastline, most notably



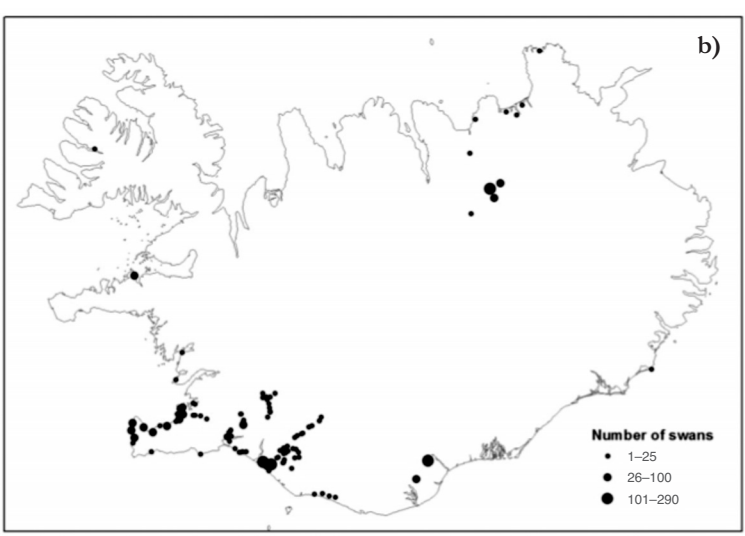


Figure 3. Distribution of Whooper Swans recorded during the international census in January 2010: a) Britain and Ireland; b) Iceland. Symbols represent total numbers recorded at a site.

along the southwest coast between Stafnes and Hvalfjörður, where a combined total of 419 birds was recorded.

There was a significant difference in the overall number of flocks across the range between the 2005 and 2010 censuses (Table 3), which is likely a consequence of the significant decrease in the number of flocks seen in Scotland and the increase in England/Isle of Man compared with the rest of the range. The latter, however, can be attributed to swans at the Ouse Washes being counted at numerous feeding sites in 2010 rather than at a single roost site as in 2005. This was confirmed on excluding the Ouse Washes from the analysis (one flock in 2005; 35 flocks in 2010), upon which there was no significant difference in the overall number of flocks across the range between censuses ($\chi^2_5 = 10.4$, n.s.) nor in England/Isle of Man compared with elsewhere ($\chi^2_1 = 0.0$, n.s.). There was still a significant difference in the number of flocks recorded in Scotland compared to the rest of the range, though to a lesser extent ($\chi^2_1 = 9.7$, $P < 0.005$), with fewer flocks than expected recorded.

The majority of flocks consisted of ≤ 25 birds, representing 65% of all flocks observed (Fig. 4). Only three flocks of > 500 individuals were recorded, these being found in England at the Ouse Washes in Cambridgeshire/Norfolk (two flocks consisting of 1,262 and 672 individuals) and at Martin Mere in Lancashire (one flock of 1,286 individuals). England/Isle of Man saw the widest range of flock sizes (Table 3), reflecting the large flocks recorded on the Ouse Washes and at Martin Mere, whilst in Scotland over 80% contained 25 or fewer birds and the majority of these held less than ten. Iceland also saw a large proportion of small flocks, but there the tendency is for Whooper Swans to disperse into very small groups.

There was a significant difference in flock size across the range between the 2005 and 2010 censuses ($W = 609065$, $P < 0.01$) (Table 3). Fewer flocks consisted of ≤ 25 individuals in 2010 (65.4%) compared with 2005 (74.5%), with a higher proportion of medium-sized flocks (26–100 birds; 19.7% in 2005 *cf.* 26.1% in 2010) and large flocks (101–500 birds; 5.8% in 2005 *cf.* 8.5% in 2010) in the most recent census. Comparing flock size within each country between the two censuses found a significant difference for Wales and England/Isle of Man (Table 3), with a higher proportion of medium-sized flocks (26–100 birds) in 2010 in both countries (0% in 2005 *cf.* 37.5% in 2010 for Wales; 18.5% *cf.* 27.6% for England/Isle of Man), and fewer with ≤ 25 birds (100% in 2005 *cf.* 62.5% in 2010 in Wales; 69.2% *cf.* 51.1% in England/Isle of Man). On excluding the Ouse Washes from this analysis, to test whether the numerous flocks recorded there in 2010 affected the results, there was still a significant difference in flock size across the range between censuses (though to a lesser extent; $W = 602574$, $P = <0.05$). No significant difference between years was found for England/Isle of Man ($W = 3949$, n.s.), however, indicating that a high proportion of the larger flocks in England were located at the Ouse Washes during the 2010 census.

Sites of conservation importance

During the census, 14 sites in Ireland and six in Britain supported numbers exceeding the

Table 3. Number of flocks and mean flock size of Whooper Swans recorded in Iceland, Ireland and Britain during the international censuses in January 2005 and 2010. The Isle of Man has been included with England for the purpose of this analysis as only one flock was observed in each year. The number of flocks recorded during the 2005 and 2010 censuses were compared using a Chi-square test with d.f. = 1 for comparison of each country with the rest of the range, and d.f. = 5 for overall comparison. Mann-Whitney tests were used to compare flock size within each country and overall between 2005 and 2010.

	2005		2010		Flock number comparison		Flock size comparison	
	Number of flocks	**Mean flock size ± s.e.**	**Number of flocks**	**Mean flock size ± s.e.**	χ^2	*P*	*W*	*P*
Iceland	126	12.3 ± 1.6	122	18.7 ± 3.4	0.1	n.s.	15402.5	n.s.
Northern Ireland	102	42.6 ± 8.5	102	45.3 ± 6.4	0.3	n.s.	10021.0	n.s.
Republic of Ireland	288	33.8 ± 3.2	284	36.8 ± 2.9	0.8	n.s.	79337.0	n.s.
England & Isle of Man	65	99.9 ± 55.1	94	96.0 ± 21.6	7.1	<0.01	4555.0	<0.05
Scotland	219	18.9 ± 2.4	145	18.3 ± 3.0	12.9	<0.001	40914.0	n.s.
Wales	11	8.5 ± 2.4	8	25.1 ± 7.1	0.3	n.s.	78.0	<0.01
Overall	**811**	**32.5 ± 4.8**	**755**	**38.7 ± 3.2**	**17.5**	**<0.005**	**609065.0**	**<0.01**

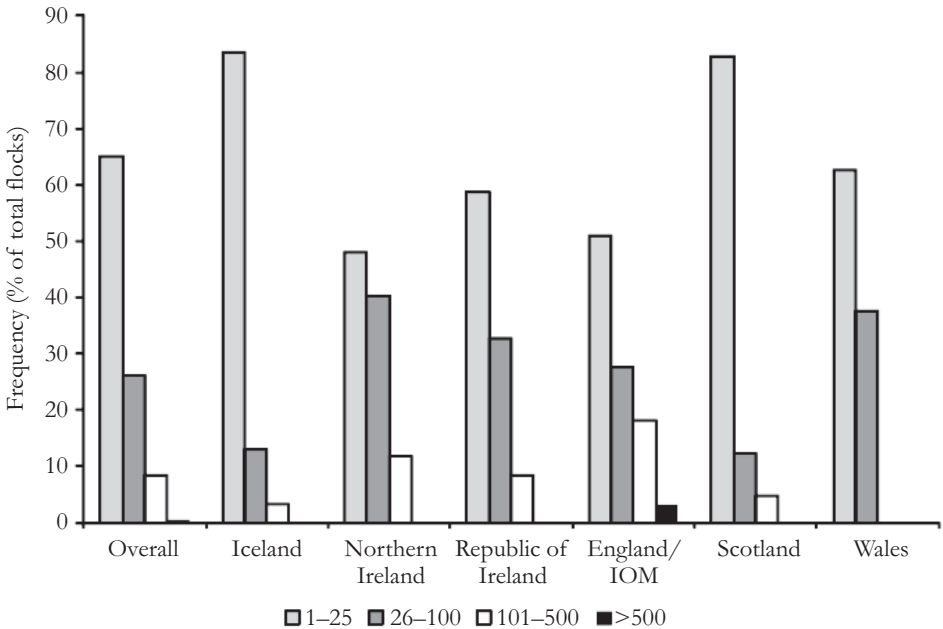


Figure 4. Frequency of flocks of each category recorded in Iceland, Ireland and Britain in January 2010. Number of flocks recorded in each country (n values) are: Iceland = 386, Northern Ireland = 102, Republic of Ireland = 284, England/Isle of Man = 94, Scotland 145, Wales = 8, Overall = 755.

current 1% threshold used to indicate sites of international importance (210 birds; Wetlands International 2006), including six that did not hold such numbers in 2005 (Appendix 1). Fifteen of these twenty sites supported at least 1% of the numbers recorded during the 2010 census (290 birds), of which four were in Britain and 11 in Ireland (Appendix 1). Ten sites that qualified in 2005 did not maintain internationally important numbers in 2010. Five sites in Britain held nationally important numbers (110; Musgrove *et al.* 2011), only two of which held these concentrations in 2005, including the Ribble Estuary which held numbers above the threshold for international importance during the previous census. Of the nine sites in Ireland which supported numbers greater than the all-Ireland threshold for site importance (130; Crowe *et al.* 2008), only Strangford Lough (which held internationally important numbers during the 2005 census) had previously qualified in 2005.

Age and brood size data

A total of 23,413 Whooper Swans was aged during the 2010 census, with the highest numbers aged in England and the Republic of Ireland (Table 4). The overall percentage of young was 16.3%, ranging from 13.8% in England/Isle of Man to 19.1% in Northern Ireland. The variation in the proportion of young differed significantly between

Table 4. Proportion of young, mean brood size and frequency of brood sizes of Whooper Swans in Iceland, Ireland and Britain in January 2010 (see Appendix 1 in Worden *et al.* 2009 for regional definitions).

	% young	Number aged	Mean brood size	Brood size					
				1	2	3	4	5	6
Iceland									
Northeast	11.6	259	1.00	2	–	–	–	–	–
South	17.0	871	2.34	16	21	10	10	2	–
Southwest	21.9	479	2.79	6	2	6	1	3	1
West	26.2	42	2.75	2	–	–	1	1	–
Total	**17.8**	**1,651**	**2.43**	**26**	**23**	**16**	**12**	**6**	**1**
Northern Ireland	**19.1**	**4,017**	**2.06**	**129**	**97**	**60**	**28**	**6**	**4**
Republic of Ireland									
Northeast	16.5	1,888	2.35	17	20	14	3	6	–
Northwest	17.6	3,224	2.22	56	52	25	22	6	1
Southeast	16.5	1,477	2.58	12	20	29	7	2	1
Southwest	15.7	1,363	2.33	26	21	18	7	4	2
Total	**16.8**	**7,952**	2.33	**111**	**113**	**86**	**39**	**18**	**4**
Ireland total	**17.6**	**11,969**	**2.21**	**240**	**210**	**146**	**67**	**24**	**8**
Scotland									
Northern Isles	25.6	133	2.13	6	4	4	2	–	–
Northwest	20.8	106	–	–	–	–	–	–	–
Northeast	12.3	65	1.17	5	1	–	–	–	–
Southwest	17.8	600	1.84	15	16	5	2	–	–
Southeast	18.3	360	2.04	8	8	6	–	1	–
Total	**18.8**	**1,264**	**1.90**	**34**	**29**	**15**	**4**	**1**	**–**
England									
Northwest	19.9	2,562	1.85	74	54	31	6	2	–
Northeast	21.4	56	4.00	–	–	–	1	–	–
East Central	11.0	5,714	1.89	137	98	59	15	2	2
South	0.0	10	–	–	–	–	–	–	–
Total	**13.8**	**8,342**	**1.88**	**211**	**152**	**90**	**22**	**4**	**2**
Wales	**18.2**	**187**	1.50	**2**	**2**	**–**	**–**	**–**	**–**
Britain total	**14.5**	**9,793**	**1.88**	**247**	**183**	**105**	**26**	**5**	**2**
Overall total	**16.3**	**23,413**	**2.08**	**513**	**416**	**267**	**105**	**35**	**11**

countries (Kruskal Wallis: $H_5 = 12.06$, $P < 0.05$), but there was no significant difference in the proportion of young between regions within each country (Kruskal Wallis: $H_9 = 8.82$, n.s, $H_4 = 6.41$, n.s., and $H_3 = 3.07$, n.s., for Britain, Ireland and Iceland, respectively; Table 4).

The overall mean brood size was 2.08 cygnets per successful pair amongst the 1,347 families assessed, only marginally lower than the previous census (2.3 cygnets), and ranged from 1.5 cygnets in Wales to 2.43 in Iceland (Table 4). Most families (69%) had relatively small broods of one or two cygnets, few (11%) were observed with four or more and no families had more than six cygnets (Table 4). A comparison of the frequency of small (1–2 cygnets) and larger (3–6 cygnets) brood sizes recorded for different countries found that a higher proportion of the larger broods were recorded in Iceland and the Republic of Ireland than elsewhere (Iceland: $\chi^2_1 = 4.7$, $P < 0.05$; Republic of Ireland: $\chi^2_1 = 17.6$, $P < 0.001$) whereas smaller brood sizes were more frequent in England ($\chi^2_1 = 14.8$, $P < 0.001$).

Habitat use

Habitat data were collected for over 80% of all swans counted. The majority of birds were seen on pasture (51.2%) and arable land (37.5%), with relatively few seen on permanent standing water (Table 5, Fig. 5).

Table 5. Percentage of Whooper Swans recorded on different habitat types in January 2010.

	Iceland	Britain	Northern Ireland	Republic of Ireland
Number of swans (*n*)	2,278	8,762	4,616	7,883
Permanent standing water	38.7	6.0	3.3	7.8
River	29.1	0.5	0	6.3
Coastal	25.6	1.9	0.1	0.4
All pasture	0.1	11.5	77.9	79.9
Improved pasture (dry)	0	6.1	71.4	52.9
Improved pasture (wet)	0	1.8	6.0	15.2
Rough/unimproved pasture (dry)	0.1	3.4	0.5	5.7
Rough/unimproved pasture (wet)	0	0.2	0	6.1
All arable	3.3	76.6	18.7	5.0
Arable growing	3.3	38.8	0	0.2
Arable waste	0	37.8	18.7	4.8
Other	3.2	3.4	0	0.6

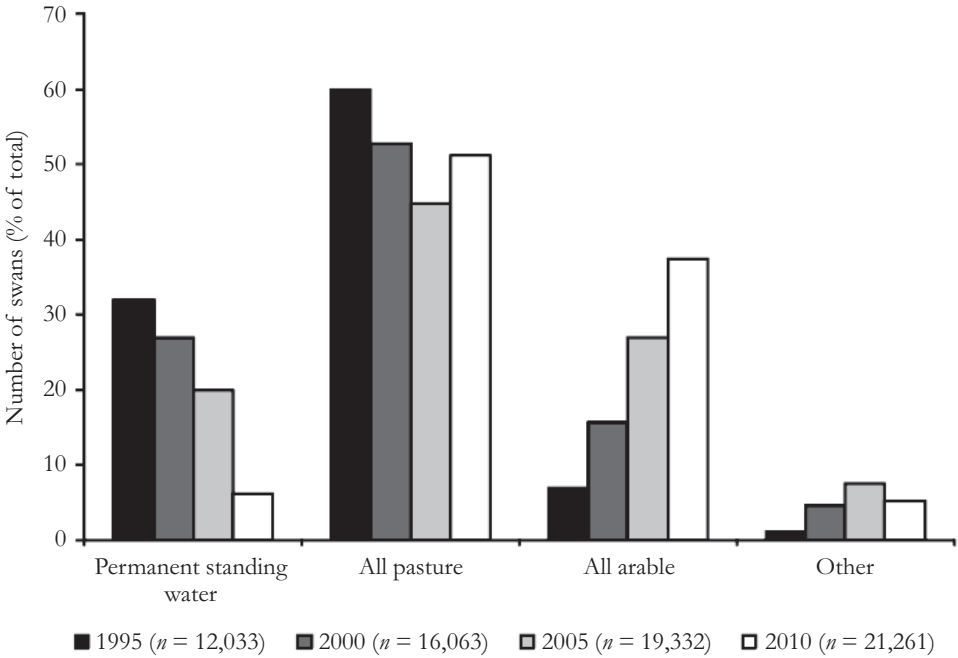


Figure 5. Distribution of Whooper Swans on permanent standing water, pasture, arable and 'other' habitats in Britain and Ireland in January 1995, 2000, 2005 and 2010.

Birds in Britain were mainly seen on arable land (with growing crops or waste) (76.6%) whilst in Ireland dry, improved pasture was the preferred habitat (71.4% in Northern Ireland and 52.9% in the Republic of Ireland). These habitat types were rarely used, if at all, in Iceland, where the majority of birds were recorded using permanent standing water (38.7%), rivers (29.1%) and coastal areas (25.5%).

Discussion

Despite the cold and snowy weather conditions experienced in Britain and Ireland prior to the January 2010 census, which made surveying conditions difficult in some areas, coverage of all sites known to be used by swans was thought to be good. A number of sites were visited in the week after the census, following a thaw across the country, and it is possible that bird movements occurred during this time. All attempts were made during data collation, however, to try to reduce the possibility of duplicate counts being included in the analysis. It has been suggested that swans may have been missed or undercounted in Ireland due to the wider distribution of birds away from their traditional sites as a result of the weather (Boland *et al.* 2010), which resulted in more effort being required to find some flocks. The number missed, however, is not believed to be notably more than during a typical season (O. Crowe pers.

comm.). It is possible that a similar situation occurred in Britain; however, indications from counters suggest coverage there was fairly extensive. Based on counts in previous years, around 120 birds may have been missed in Iceland due to a few areas not being surveyed. This represents just over 5% of the total recorded for Iceland in 2010 but only 0.4% of the overall census total. The total presented in this report, therefore, is thought to be an accurate estimate of the population size of Icelandic Whooper Swans in January 2010.

The total of 29,232 Whooper Swans was the highest to date, representing an 11% increase on the total counted in 2005. It continues the period of sustained growth that has occurred since the 1995 census although the rate of increase was lower than seen previously, with an increase of 31% recorded between the 1995 and 2000 censuses, and 26% between 2000 and 2005.

An increase in wintering numbers was evident in all countries across the range, except for Scotland where numbers were lower than in 2005. The rate of increase in Ireland and the Isle of Man was lower than that of the population as a whole. Conceivably, the cold weather in Britain and Ireland in December 2009 and January 2010 affected the distribution of swans, pushing birds southwards, although similar weather conditions were experienced across both islands. Some evidence for this could be inferred when comparing total numbers between the 2005 and 2010 censuses, with many northern counties in Scotland holding considerably fewer birds in 2010, while the southern county of Dumfries and Galloway saw a marked increase. The census total for England was also notably higher, mainly due to the large increase at the Ouse Washes (Cambridgeshire/Norfolk) but there was no major increase in any of the northern counties in England. As supplementary feeding occurs at WWT centres during the winter (located at Caerlaverock in Dumfries & Galloway, Martin Mere in Lancashire, and Welney in Norfolk) birds may have moved to these sites during cold weather as they can be assured of easy access to food. In Ireland, swans had moved away from their traditional areas and were absent from many regular sites and were reported in places where they had not been recorded before (Boland *et al.* 2010). This may also have been the case in Scotland, resulting in birds being missed, but it is thought unlikely that this would account for such a large difference in the census totals between 2005 and 2010.

There has been some evidence that other species of wildfowl, such as Bewick's Swan *Cygnus columbianus bewickii*, are tending to winter closer to their breeding grounds with the milder winters of the early 2000s (Worden *et al.* 2006). Since the 1991 census, however, there has been a significant increase in the proportion of the overall population of Whooper Swans wintering in England, with a corresponding decrease in Scotland, though to a lesser extent. There has also been a downward trend in the proportion recorded in Ireland, significantly in the Republic of Ireland. Only England has seen a consistently higher rate of increase in numbers when compared with the overall population increase. This would suggest that the population as a whole is shifting its range south and in 2010 this may have been exaggerated by cold weather

movements. In Scotland and Ireland, Whooper Swans are widely distributed across many sites. In contrast, Whooper Swans in England continue to be concentrated at just a few sites, the majority at Martin Mere and the Ouse Washes. Both sites have seen a sustained increase in numbers since the 1995 census, with 1.8 and 5.4 fold increases occurring, respectively. The disproportionate increase seen in England is predominately a result of the increase at the Ouse Washes, where in 2010, the increase accounted for 89% of the rise in total numbers recorded in England. A similar southerly shift in the wintering distribution of the Iceland/Greenland population of Pink-footed Goose *Anser brachyrhynchus* has also occurred (Gill *et al.* 1997), with an increasing proportion of the population being recorded in Norfolk, the most southerly region in Britain where these birds winter. The most likely cause of this is the birds' preference for foraging on post-harvest sugar beet waste, a crop that was increasing in Norfolk at that time, partly because it is highly nutritious and partly because birds can feed largely undisturbed by farmers because this is a by-product of no commercial value. It is possible that Whooper Swans are moving south for similar reasons, though more investigation is required to determine whether habitat choice is the determining factor.

It is also possible that an influx of birds from the Northwest European population, which breeds from Fenno-Scandia to northwest Russia and winters in northwest and central mainland Europe, has added to the numbers recorded during the census. Laubek *et al.* (1999) suggested that the large increase in the Northwest European population since the 1980s has resulted in an increasing number of these birds wintering in Britain, particularly in southeast England, and these movements may be influenced by severe weather. In January 2010, mainland Europe also experienced very cold and snowy conditions. Numbers of Whooper Swans in the Netherlands (the southern end of the wintering range of the Northwest European population) were only slightly higher than during previous years of milder winters, however (2,212 in 2010 compared with 2,184 in 2009), and the monthly trend was also similar to that of previous years, with peak numbers recorded in January (Hornman *et al.* 2012). The highest numbers were observed in the east of the Netherlands, indicating that a small number of birds may have moved in from further east/northeast, as is often the case during colder winters (Ridgill & Fox 1990; M. Hornman pers. comm.), but there were no clear indications for an influx of swans from mainland Europe into southeast England (the area closest to Whooper Swans sites in mainland Europe) during winter 2009/10 winter. For instance, there were no reported sightings in Britain in winter 2009/10 of ringed Whooper Swans from the Northwest European population (K. Brides pers. comm.). A census of Whooper Swans in Iceland in the late summer/autumn prior to an international census may help to provide further insight into the level of influx of birds from the continent (estimated at a few hundred birds in the 1990s; Laubek *et al.* 1998), albeit that this may vary with annual variation in weather conditions. Undertaking the population censuses within

Iceland rather than on the wintering grounds would help to resolve the issue of whether immigration/emigration is occurring but, given that Whooper Swans are widely dispersed across Iceland during the summer, and move from moulting to staging areas in the autumn (Gardarsson & Skarphedinsson 1984), the practicalities of undertaking such a survey would need to be considered with care.

Many of the British and Irish sites supporting internationally important numbers in 2005 did so in 2010, although some saw considerable variation in total numbers. There was a marked change, however, in the list of sites supporting nationally important numbers. Only two sites in Britain maintained qualifying numbers between the two censuses, whilst all those holding more than the all-Ireland threshold did not do so in 2005, with the exception of Strangford Lough, which was formally internationally important. These differences are, in part, likely to relate to the change in distribution caused by the cold weather in January 2010, with swans in Ireland using areas away from their traditional sites and the possible shift south in Scotland. Given this, it is difficult to conclude whether the variation in qualifying sites is indicative of a genuine shift in wintering sites used.

The 2010 results show a small increase in the proportion of the population overwintering in Iceland following a period of stability between 1995 and 2005, with the rate of increase in total numbers between the 2005 and 2010 censuses being much higher than that of the overall population (46% in Iceland compared with 11% overall). This alone provides little evidence, however, of a shift in the distribution of the population, *i.e.* an increasing proportion wintering closer to their breeding grounds in Iceland, hence further monitoring is required to see whether this upward trend continues.

Although no significant difference was found in the proportion of young recorded across regions there was considerable variation, ranging from 26.2% in west Iceland (small sample size) to 11.0% in east-central England. In Britain and Ireland, the highest proportion of young was found amongst flocks in the Northern Isles of Scotland, northwest Scotland and northwest England (excluding northeast England where only a few birds were aged). There was a significant difference in the frequency of brood sizes between countries, with larger families observed in Iceland and Ireland, reflected in the mean brood size which was highest in various regions of these countries. This variation in breeding success may reflect the preference for Whooper Swan families to stay closer to their breeding grounds, with non-breeding birds travelling further south (Rees *et al.* 1997).

Analysis of habitat use by Whooper Swans during the international censuses suggest a steady decline since 1995 in the use of permanent standing water with a corresponding increase in the use of arable land. It should be noted, however, that weather conditions in 2010 are likely to have had a strong influence on habitat choice, with many waterbodies being frozen for a long period of time and, in some regions, swans were observed in areas away from

their usual sites. Similarly, it was suggested that wet, often flooded conditions during the 2005 census may also have influenced habitat selection, away from permanent waterbodies towards flooded grassland (Worden *et al.* 2009). The difference in habitat use is, however, noticeable between all censuses since 1995 which would suggest that swans are potentially altering their choice of feeding habitat. Further investigation and research is, however, needed to assess to what extent this is truly occurring.

The WeBS 2010 January count recorded a total of 10,996 Whooper Swans in Britain and Northern Ireland (Holt *et al.* 2011), which represents 67% of the census total for the country, highlighting the fact that WeBS misses a proportion of the population. This, together with the possibility that more birds may be wintering in Iceland, emphasises that a species-specific census is necessary to produce an accurate estimate of population size. Annual indices derived from WeBS data follow a trend similar to that calculated from the international censuses, indicating a pronounced increase in numbers from the mid- 1990s to the early 2000s in Britain, followed by a more steady increase up to 2009/10 (*i.e.* the latest year for WeBS data Whooper Swan trends published to date), whilst for Northern Ireland the index shows a very gradual increase in wintering numbers. This suggests that WeBS currently provides a reasonable indication of the trend in the Icelandic Whooper Swan population.

Results from the 2010 census show a sustained growth in the Icelandic Whooper Swan population and provide further evidence of a southerly shift in its wintering distribution. The increase in numbers may be attributable to several good breeding seasons for the population in the early 21st century, with the proportion of young present in wintering flocks estimated at 15.4%, 20.7%, 16.8%, 15.4% and 16.3% in 2006/07–2010/11 inclusive (Wildfowl & Wetlands Trust 2011), but survival analyses are required to determine any changes in mortality rates over time. Continued monitoring is required, however, to clarify whether this shift is sustained and to what degree the cold weather in 2010 may have exaggerated the pattern of occurrence, particularly given that results from the 2005 census suggested the proportion of swans wintering in Scotland was starting to increase.

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Appendix 1. Sites in Britain and Ireland exceeding current 1% thresholds for international importance (210; Wetlands International 2006) and national importance for Britain (110; Musgrove *et al.* 2011) and Ireland (130; Crowe *et al.* 2008) in January 2010, with the percentage change in numbers compared with the 2005 census.

Site	County	No. of swans in 2010	% Change from 2005
Sites of international importance in Britain and Ireland			
Ouse Washes (arable)	Cambridgeshire, Norfolk	5,632	66
Martin Mere & surrounding area	Lancashire	2,052	19
Loughs Neagh and Beg	Antirm, Armagh, Down, Londonderry, Tyrone	1,803	19
Lough Foyle	Donegal, Londonderry	883	–7
Upper Lough Erne	Fermanagh	799	29
Cashen River & Estuary	Kerry	506	121
Wexford Harbour & Slobs†	Wexford	411	204
River Foyle	Donegal, Londonderry, Tyrone	389	–12
Shannon Callows	Galway, Offaly, Roscommon, Tipperary, Westmeath	364	–16
Lough Oughter Complex	Cavan	361	33
Shannon & Fergus Estuary	Clare, Kerry, Limerick	339	54
Lough Swilly	Donegal	338	–33
Nene Washes†	Cambridgeshire	337	327
River Suck (Aerial)	Galway, Roscommon	331	2

Appendix 1 (*continued*)

Site	County	No. of swans in 2010	% Change from 2005
Solway Estuary	Dumfries & Galoway, Cumbria	290	–43
Little Brosna Callows†	Offaly, Tipperary	279	1,016
Lough Iron†	Westmeath	261	+
Blackwater Callows	Cork, Waterford	225	–57
Pear Tree Grove, Pilling Moss†	Lancashire	215	+
Kelton Mains†	Dumfries & Galloway	210	+
Sites of national importance in Britain			
Wigtown Bay	Dumfries & Galloway	177	19
Ballone†	Highland	142	+
Ribble Estuary*	Lancashire	119	–67
Abbey House, Abbeytown†	Cumbria	116	+
Loch a`Phuill (Tiree)†	Strathclyde	115	1,050
Sites of All-Ireland importance in Ireland			
River Blackwater (Meath)†	Meath	207	+
River Lagan†	Antrim, Down	204	1,569
River Boyne†	Meath	190	+
The Cull & Killag†	Wexford	181	71
Mullaghmore (Moylough/ L. Nalarsagh)†	Galway	174	81
River Moy†	Mayo	169	635
Strangford Lough*	Down	138	–41
Foxhall/Cloghans Hill†	Galway	136	+
East Ballinamore Lakes†	Cavan, Leitrim	135	16

† Site did not qualify during the 2005 census.
* Site was of higher importance status during the 2005 census.
+ Site held no birds during the 2005 census.

Sites that did not maintain either internationally or nationally important numbers between the 2005 and 2010 censuses: Farmland near South Kinkell (Perth & Kinross), Finn-Lacky Catchment (Monaghan Fermanagh), Glen Lough (Westmeath), Loans of Tullich/Cromarty Firth (Ross & Cromarty), Loch Insh & Spey Marshes (Inverness), Loch Leven (Fife), Loch of Strathbeg (Aberdeenshire), Lyonstown Stud Farm (Tipperary), North Central Galway Lakes (Galway), Rinn Lough Lakes (Leitrim), River Isla; Bridge of Crathies (Perth & Kinross), River Tweed Norham (Northumberland), Tacumshin Lake (Wexford), Tara Mines Tailings Ponds (Meath), Tralee Bay, Lough Gill & Akeragh Lough (Kerry), Turraun Nature Reserve (Offaly), Wetlands east of Ballinrobe (Mayo Galway).

