Increase and changes in distribution of breeding Whooper Swans *Cygnus cygnus* in northern Sweden from 1972-75 to 1997.

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In the early decades of the 20th century the Whooper Swan was a rare breeding bird in northern Sweden, estimated at only 20 pairs. After protection from hunting in 1927, the population increased slowly and then more markedly after 1950. A large scale aerial survey was undertaken in 1972–75, when the population of the two northernmost provinces of Sweden (118 000 km²) was estimated at 310 pairs. These provinces were re-surveyed in 1997, producing an estimated 2,775 pairs. In 1997, breeding Whooper Swans were found in all areas between the coast and the mountain chain, whereas the distribution in the 1970s was restricted to some core areas in the north and to scattered pairs. Whooper Swans showed a clear association with wet mires and small lakes. The increase in the population is probably related to increased protection, as well as to better feeding conditions in the agricultural areas in the wintering quarters, thought to have improved the swans' condition at the start of the breeding season.

Key Words: Breeding Population, Whooper Swan, North Sweden, Population Changes.

During the nineteenth century the Whooper Swan Cygnus cygnus was a wide spread breeding bird in the northern half of Sweden, where it was found to the east of the high mountain chain in areas of large mires but not by the coasts (Arvidsson 1987, Fjeldså 1972). It is uncertain how far south the distribution reached in former days. The population decreased markedly due to heavy hunting during the second half of the nineteenth century and the first decades of the twentieth century, and it is generally assumed that the population reached a low of about 20 pairs in the 1920s. The few remaining breeding pairs were found in the remote and vast mire areas in northernmost Lapland.

The Whooper Swan was afforded protection

from hunting in 1927, and spread to breed in the inner parts of Lapland. A breeding population was also established by reintroduction to the province of Jämtland. Before 1950 it had slowly spread to a number of sites in northern Sweden, but the distribution was still very patchy. After 1950, the rate of dispersal increased and breeding birds occurred even in the southernmost province of Scania in the 1960s. Breeding records were eventually reported from most Swedish provinces.

Arvidsson (1987) summarised the situation throughout Sweden in the mid-1980s and estimated the Swedish breeding population to be 500 pairs, this being the first total estimate since the 1920s (Fjeldså 1972). Both of these estimates were based on local counts and spontaneous reports of swan observations obtained by local report committees, however, and not on any full survey. The uneven spread of counts and observers especially in the north makes these estimates very uncertain. In the northern part of the country, extensive aerial surveys were undertaken in 1972-75, when the whole of northern Fennoscandia (Sweden south to 65°, Norway south to 68° and Finland south to 64°) was censused for breeding waterfowl (Haapanen & Nilsson 1979). During this North Calot Survey (NCS), about 310 pairs (120 with nests) were found in the northern third of Sweden.

From the general bird reports and from the winter surveys, both in Sweden (cf. Nilsson 1996, 1997) and internationally (Rose 1996), it was clear that the increase in the number and distribution of Whooper Swans breeding in Sweden has continued. The Research Committee of the Swedish Ornithological Society therefore decided to undertake a survey of the Whooper Swan breeding population in 1997. As there were also reports on marked changes in the distribution and numbers of breeding birds from northern Sweden, we decided to repeat the earlier surveys of 1972-75, this time concentrating on the Whooper Swan only, which made it possible to undertake the survey during a restricted time period.

During the period 31 May to 6 June 1997 we covered the transects of the NCS by light aircraft, with the exception of the parts in the mountain chain lacking suitable swan breeding habitat. Whereas the old survey covered Sweden north of 65°, we extended the present survey to include the part of the province of Västerbotten south of this latitude. Moreover the coverage was extended in some woodland districts included in the NCS.

Study area

The study area extends from the northern and westernmost borders of Sweden south to a latitude of about 64° N. Detailed descriptions of the northern parts of the study area, included in the NCS, are found in Haapanen & Nilsson (1979), who divided this area into six regions (A-F, **Figure 1**). In the present study

the southern part of the province of Västerbotten is the seventh region (G). The topography of northernmost Sweden is dominated by the Scandinavian mountain chain in the west, with altitudes normally of up to 1,000-1,500 m (in some parts 1,500-2,000 m) in the mountains and 400–500 m in the valley bottoms. The mountain chain forms the major parts of regions A-C. In this study only the easternmost parts of these regions were included, together with some of the large valleys in the alpine region that have suitable swan habitats.

Region D lies completely within the woodland zone. The main wetland areas lie at an altitude of 200-500 m. Boreal forest and mires are the dominant vegetation types, mires covering more than 20% of the total area (5% of the total area consists of wet mires). Most lakes are fairly small (<1-2 km²), and shores are dominated by mire vegetation.

Region E is a transition zone between the mountain chain and the more low-lying parts to the east. Coniferous forest dominates. Many large lakes (up to a few hundred km² are found in this region, but there are also smaller wetlands suitable for swans. Most wetlands are found at altitudes of 400-500 m. Wet mires occupy about 1.8% of the total area.

Region F lies in the central boreal zone and is dominated by coniferous forest and mires (10% of the total area is mires). The wetland areas are found at an altitude of 0-400 m. Most lakes are fairly small (<1-2 km²). This region had the highest percentage of shores with rich vegetation in the NCS: 7.5%. Region G was not included in the NCS so habitat data are not available. It is of similar character to region F.

Methods

For the NCS, transects covering the entire northern Fennoscandia were established using the UTM (Universe Transverse Mercator) coordinate-system (Haapanen & Nilsson 1979). 5×5 km squares (25 km^2) were laid out along the diagonals of the 100 \times 100 km squares, extending from the Atlantic coast or Norwegian/Swedish border to the Finnish/Russian border or Bothnian Bay. In



Figure 1. Map of northern Sweden showing the geographical position of the transects and the division into regions (A-G). The western-most squares in each transect, close to the mountain chain, are connected with a line. To the west of this line there are no squares with potential swan habitat in the transects. Borders between the provinces are also shown.



Figure 2. The geographical position of the study areas with potential Whooper Swan habitat (see Table 3).

the mountain chain (regions A-C), and in the upper parts of the forested zones, extra transects of squares were inserted between the main transects, resulting in a 10% coverage of the area, compared to 5% for parts covered only by the main transects. For further details see Haapanen & Nilsson (1979), where maps of the area and geographical details are given.

For the 1997 survey the same system was used (Figure 1) but the 'extra' transects were

extended all the way to the coast and covered completely. The transects were covered westwards up into the mountain chain as far as potential swan habitats were available. Transects were also extended to cover the entire province of Västerbotten.

In addition to the system of transects (surveyed in 1973–1975), a number of study areas containing important wetland areas in the mountain chain (**Figure 2**), and the large mires close to the mountain chain, were surveyed

each year from 1972 to 1975 to study annual variations in the waterfowl populations using these sites. In 1997, all study areas were again surveyed, with some potential swan areas to the south of the 1972-75 study areas also covered. All Whooper Swans recorded outside the squares and transect areas, such as during transport flights etc, were also recorded together with site co-ordinates.

The NCS aimed to cover all breeding waterfowl species within the squares and special study areas. Thus, all wetland areas in the squares of the transects were surveyed from an altitude of about 30-50 m, using highwinged Cessna aircraft, flying at slow speed. Two observers, plus the pilot, were generally used, and all wetland areas were inspected at close range. The same procedure was repeated in 1997, but because Whooper Swans are large and conspicuous flights were made at 100-150 m to obtain a better overview. As in the NCS all wetlands in the entire squares of the transects were inspected closely to establish the occurrence and number of Whooper Swans and the birds sighted were checked at close range for the presence of nests.

In 1997, 481 5 x 5 km squares (*ie* a total of about 12,000 km²) were covered in the transects flight, or about 10% of total area of 118,300 km² in the two provinces (**Table 1**). Of these squares, 328 had been covered in 1972-75. Additionally, 2,430 km² were covered in study areas in 1997 (**Table 2**).

To obtain an estimate of the population size in the different regions, the total number of pairs recorded in the transect squares (and pairs seen with nests) were multiplied by a factor (total area in squares/total area of region) related to the degree of coverage in the regions. For further discussions of the applicability of this simple method see Haapanen & Nilsson (1979).

During the NCS a range of habitat data were collected for the squares surveyed (Haapanen & Nilsson 1979). Data recorded for each square in the NCS included I. main habitat types (eg proportion (0.1) of squares with birch forest, coniferous forest, mires, alpine heath, rock etc), 2. altitude of wetlands (100 m intervals), 3. total area and shore lengths of lakes of different sizes, 4. total area of wet mires, 5. main shore types (eg proportion (0.1) of shores with rich vegetation, poor vegetation, bare shores, mire shores etc), and 6. geological background. These data were used to analyse the influence of habitat variables on the distribution of Whooper Swans across the squares covered by the NCS. Habitat data were not recorded for the additional squares included in 1997. Presence of Whooper Swans in squares classified as to habitat variables was tested by χ^2 analysis. The influence of wetland area (wet mires + lakes <10 ha and delta areas) and altitude of wetlands was tested by stepwise multiple regression. Statistical analysis were undertaken with SYSTAT (Wilkinson 1990).

Results

Population size

During the 1997 survey, 178 pairs of Whooper Swan were recorded with nests in the transects, with an additional 144 pairs with nests in the study areas and in other wetlands outside the squares of the transects. A further 102 pairs without nests were recorded in the transect squares and 89 were found outside the squares (**Table 1**). Moreover 167 single and grouped swans were found in the squares (70 outside). On an individual basis, 51% of the Whooper Swans had nests, 30% were paired but without nests and 19% were single or occurred in groups (total n = 1,263).

Extrapolation of the number of Whooper Swans found in the transects to the total surveyed area of the provinces of Västerbotten and Norrbotten (118,000 km², the mountain chain excluded) gave an estimated total population in 1997 of 2,775 pairs, 1,760 pairs with nests (**Table 1**). Marked differences were found between regions, with an estimate of only 55 pairs (25 with nests) in the mountain chain and 1,100 pairs (760 with nests) in the northernmost woodland and mire region (D, **Figure 1**).

For the early 1970s, Haapanen & Nilsson (1979) estimated that the total breeding population in northern Sweden (regions A-F in Figure 1) was 310 pairs during the early 1970s, Table I. Number of pairs of whooper Swans in the squares of the transects in different regions (Figure I) of northern Sweden 1997 and estimated population size and density in different regions.

Region	Number of squar es	Total area Km²	Numbe in squa	Number of pairs in squares			Total estimated population		Density	
			With nests	Without nests	% with nests	With nests	Total Pop	Nests/ 100km²	Pairs/ 100 km²	
A	30	6400	3	I	75	25	35	0.39	0.53	
В	21	3480	0	3	0	0	20	0.00	0.57	
С	4	960	0	0	0	0	0	0.00	0.00	
D	27	31200	76	35	68	760	1110	2.43	3.55	
E	52	13500	17	10	63	170	280	1.30	2.07	
F	137	30700	58	32	64	520	805	1.69	2.62	
G	110	32100	24	21	53	280	525	0.87	1.64	
TOTAL	481	118340	178	102	64	1760	2775	1.49	2.34	

Region	Number of Squares	All Pairs (with nests +	without nests)	Unpaired individuals		
		1973-75	1997	1973-75	1997	
А	30	1+3	3+1	0	2	
В	21	0+0	0+3	0	I	
С	4	0+1	0+0	0	I.	
D	125	8+17	76+35	8	27	
E	49	0+3	14+9	3	П	
F	99	3+1	49+26	5	23	

Table 2. Total number of Whooper Swans counted in squares of the transects surveyed both in 1973-75 and 1997

of which 120 had nests. The coverage in the 1997 survey was larger, extended to include region G, but from other sources we know that there were no breeding Whooper Swans in region G in the 1970s. In all, 328 squares were covered in both periods; they contained 12 nests in the 1970s and 142 in 1997. The numbers of pairs without nests were 25 and 74 respectively (**Table 2**).

Compared to the former period, a much higher proportion of the swan pairs recorded in 1997 had a nest (64% (**Table 1**) compared to 32% (n=37) in 1972-75; ($\chi^2 = 13.2$, P<0.001, df=1).

For the study areas of the NCS, a total of 18-27 pairs was recorded in the 1970s (6-8 nests) compared to 68 pairs (43 nests) in 1997 (**Table 3**). In Sjaunja (see **Table 3**, and **Figure 2**), which had the highest number and density of Whooper Swans during the earlier survey, six nests (12 pairs) were found in 1974 compared to 11 nests (20 pairs) in 1997. Unfortunately, the other core area west of Sjaunja could not be covered fully in 1997 due to late ice melt.

Distribution

In 1972-75, the swans nesting in northern Sweden were concentrated in the northernmost part of the province of Norrbotten, where they were found on the lakes and large mires east of the mountain chain. No pairs were found close to the coast (**Figure 3a**). The maps show the number of swan pairs (and nests) in the squares of the transects, with a marked concentration on the big mires around Sjaunja and Kaitum apparent in 1973-75. In the study areas in this region, no less than 22 pairs (12 nests) were found. The study areas are not included in the maps as they would bias the picture, but no areas comparable to Sjaunja and Kaitum (M, N in **Figure 2**) are to be found.

In 1997, the Whooper Swans were spread over the entire provinces of Västerbotten and Norrbotten, although the species was still much more common in the northern part than in the south (**Figure 3b**). The southernmost transects in Västerbotten still had rather few pairs, and the number of nests was especially

				6	12 22 17 22				
Stud	dy area	Habitat Type	Total area (km²)	1972	1973	974	1975	1997	
	Blaikmyran	Mires + small lakes	210		-	-	-	0+0	
R	Holmsjömvran	Mires + small lakes	165	_	-	-	-	3+2	
C	Maskan	Mires + small lakes	36	-	-	-	-	0+0	
D	Skarvsiömyrarna	Mires + small lakes	96	-	-	-	-	2+3	
E	Labbatmyrarna	Mires + small lakes	60	-	-	-	-	0+0	
F	Lycksamyran	Mires + small lakes	245	-	-	-	-	2+7	
G	Kvickjokk	Delta	17	0+0	0+1	0+0	0+0	1+0	
н	Rapadalen	Delta in alpine valley	35	2+0	2+0	[+]	1+2		
К	Muddus	Large aape mires + lakes	242	-	-	÷	0+4	16+8	
L	Sjaunjaape	Large aape mires + lakes	188	2+6	3+7	6+6	?+9	+9	
Μ	Sjauna west	Large aape mires + lakes	30	-	-	-	0+2	+	
Ν	N Satisjaure	Mires + small lakes	298	4+3	5+7	5+2	?+	-	
Ρ	Kaitum	Mires + small lakes	210	0+1	0+0	+	-	9+5	
R	Latjojaure-Vistasvagge	Delta in alpine valley	21	0+0	0+0	0+0	0+0	2+0	
S	S Tsåktso-Vuomajaure	Palsa peatland + small lakes	247	2+0	+	1+2	0+3	I+0	
Т	Pirtimäsvuoma	Palsa peatland + small lakes	99	0+5	0+2	0+0	0+2	l +0	
U	Tsåktso	Palsa peatlands + small lakes	171	+	0+1	0+1	0+1	0+0	
٧	Tavvavuoma	Palsa peatlands + small lakes	67	1+2	0+4	0+0	0+4	0+0	

Table 3. Number of Whooper Swan pairs (with nests+without nests) recorded in different study areas (Figure 2) during 1972-75 and 1997

Note: Areas U and V were mostly ice-covered in 1997



Figure 3. The distribution of Whooper Swan pairs (with and without nests) and nests, respectively, in the transects at the surveys in 1973-75 (A) and 1997 (B), respectively. The dotted line shows the southern border of the area surveyed in 1973-75.

low. Otherwise the Whooper Swan was well spread all the way from the mountain chain to the coast.

Although Whooper Swans occurred all over the province of Norrbotten, there was a marked concentration of pairs, and especially nests, in areas with large mires. Perhaps related to this, a much higher proportion of the swans were without nests in the southern part of the range than in the older core areas of Norrbotten (cf. Figure 3).

Most Whooper Swans were found outside the mountain chain, but some of the richer valleys in the high alpine regions held breeding pairs. Thus two nests were found most years in the early 1970s in the isolated Rapadalen (area H), a mountain valley with generally very rich waterfowl habitat in the high-alpine Sarek National Park, well separated from all other Whooper Swan areas.

There was still a breeding pair in Rapadalen in 1997 and pairs with nests were also found at Kvickjokk (G) and Vistasvagge (R), where no Whooper Swans occurred in the 1970s.

Habitat selection

Large parts of inland Norrbotten and Västerbotten (*ie* most of the region east of the mountain chain) are situated at altitudes of 200 to 500 m. The majority of Whooper Swan nests were therefore found at these altitudes. Only one pair of the breeding swans seen along the transects was found above 500 m. The same was true for the study areas despite single nests being found higher during the NCS. A number of pairs were found at 400-500 m but the proportion of squares with nesting pairs was significantly lower than for squares at lower altitudes (**Table 4**, ($\chi^2 = 30,0, df = 5, P < 0.001$).

Apart from altitude, no habitat factor seemed related to the breeding distribution of swans with the exception of the occurrence of wet mires. For squares with at least 10% mire, 65% (n = 46) supported at least one pair of breeding Whooper Swans, compared to 35% for those squares (n = 271) without any large areas of wet mire (<10%), the difference being highly significant ($\chi^2 = 11.6$, df =1, P < 0.001). Among squares with a high proportion of wet mires

there were no differences in swan usage between northern and southern areas.

Using stepwise multiple regression analysis, altitude and the area of wetlands (wet mires + delta areas + lakes less than 10 ha) proved to be significant factors (F = 17.9, df = 3, P < 0.001), whereas the total area of mires did not. However only a small proportion of the total variation in the number of nesting pairs ($R^2 = 0.14$) was explained by these variables. Other habitat variables did not have any clear influence on the distribution of Whooper Swans in northern Sweden.

Discussion

The aerial surveys demonstrate that the breeding Whooper Swan population in the two northern-most provinces of Sweden has increased markedly since the last survey in the mid 1970s (Haapanen & Nilsson 1979). The increase over the near 25 year period was about 10-fold, which is much higher than the increase in the wintering population in southern parts of the country (from about 2,000 in the early 1970s to 8,000 in 1995; Nilsson 1997), and in the overall wintering populations in continental north-western Europe (Rose 1996). Similar increases were reported from other parts of Sweden; in the province Hälsingland in central Sweden, aerial surveys were undertaken in 1994, when 175 pairs were estimated in a province where 20 years ago no breeding swans occurred (Persson et al. 1994).

A comparison between the censuses undertaken in the 1970s (Haapanen & Nilsson 1979) and in 1997 (present study) shows not only an increase in the population in the areas surveyed on both occasions, but also an expansion to new areas. There were no pairs with nests in the province of Västerbotten during the first census, whereas swans were well established in the region during the present survey. A similar expansion of the distribution is evident from the reports of increasing swan populations in the southern parts of the country. Even if the population has increased in all parts of the large study area, a very large part of the overall increase is

Altitude (m)	0-100	101-200	201-300	301-400	401-500	500+
Without pairs	2	4	7	22	25	8
With pairs	3	6	10	17	14	1

Table 4. Number of 5 x 5 km² squares in the transects at different altitudes with and without pairs of Whooper Swans. Only squares with more than 50 ha of wetland (wet mires + small lakes + delta area) are included.

explained by dispersal of the species to almost all parts of the provinces where suitable habitat is available. This is illustrated by the overall increase being ten-fold, whereas the population has only increased with a factor of three in the old core areas around Muddus, Kaitum, and Sjaunja (K, L, M, P in **Figure 2**).

According to Haapanen *et al.* (1973), the northern limit of the distribution of the Whooper Swan is situated where half of the summers are too short for the cygnets to reach fledging, the critical length of time needed to fledging being about 140 days. In the northern part of the breeding range (*ie* in the core areas of the early 20° century), Whooper Swans were breeding close to their northern limit, and not in the optimum area which is to be found much further south in Fennoscandia.

Thus the expansion of the Whooper Swan in Fennoscandia in recent decades, implying both an increase in range and an increase in the population in the inhabited areas, is most probably a re-invasion of its former distribution area after the relaxation of hunting and persecution. As the productivity of Whooper Swans is very much influenced by the conditions in the winter guarters (Nilsson 1979), in the same way as the feeding situation in the winter and staging areas of geese is important for their breeding results (Nilsson & Persson 1996), it is most probable that changes in agriculture in recent decades, such as the introduction of new crops and changed harvesting methods have helped to speed up the increase in the Whooper Swan population (Nilsson 1997). As for most Eurasian geese, improved feeding conditions in agricultural areas has increased the likelihood of Whooper Swans being in good condition at the start of the breeding season. Further, as the Whooper Swans expand to new areas they will experience less competition from conspecifics and more favourable climatic conditions. This could lead to an even faster future increase in the Whooper Swan population. The increase in the numbers of Whooper Swan in Fennoscandia is similar to the increase noted in several goose populations in Europe in recent decades (*cf.* Madsen *et al.* 1996).

In the breeding areas, the Whooper Swans were found mostly on small lakes with lush vegetation or in peatlands and mesotrophic areas (Haapanen *et al.* 1977, present study). Mires of the preferred type are very abundant in northern Sweden and Finland, suggesting that the availability of suitable breeding habitats is not yet a limiting factor for the expansion of the Whooper Swan population in Fennoscandia (Haapanen *et al.* 1977, Haapanen & Nilsson 1979).

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