POPULATION TRENDS AND BREEDING SUCCESS OF CLIFF-NESTING SEABIRDS IN ORKNEY, 1976-98

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Population trends of Northern Fulmars, Kittiwakes, Common Guillemots and Razorbills have been monitored in sample plots at five colonies in Orkney since 1976; several complete counts of these colonies were also made. Numbers of Fulmars, Guillemots and Razorbills attending the colonies in the breeding season increased from 1976 to 1997. However, for all three species, the overall increase was punctuated by a period of decline in the early 1980s; there was also some variation between colonies in population trends. In contrast to the other species, breeding numbers of Kittiwakes declined by an average of 2.5% per annum *over the same period, the overall rate of decline being inversely related to colony size. Breeding success of Fulmars, Kittiwakes and Guillemots was monitored annually for varying periods from the mid 1980s to late 1990s. Breeding success of both Fulmars and Guillemots was close to or above national averages in most years. Kittiwake breeding success was generally very high in the past 10-15 years, so the declining population appears paradoxical. Large-scale mortality of fledglings in some years, particularly the late 1970s, may be partially responsible but the continuing decline of the Orkney Kittiwake population remains to be fully explained.*

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INTRODUCTION

The Orkney Islands, off the north coast of Scotland, hold major concentrations of breeding seabirds. In the mid-1980s, when seabirds were last comprehensively censused in Britain and Ireland, Orkney held almost 400 000 pairs of 22 species, including 15% of the British breeding population of Northern Fulmars *Fulmarus glacialis*, 13% of Kittiwakes *Rissa tridactyla*, 17% of Common Guillemots *Uria aalge* and 7% of Razorbills *Alca torda* (Lloyd *et al.* 1991).

In 1976, in view of the vulnerability of these four species to oil spills and other environmental changes, the former Nature Conservancy Council (now Joint Nature Conservation Committee) established a programme to monitor changes in their numbers at five colonies on Mainland Orkney - at Row Head, Marwick Head and Costa Head on West Mainland, and at Gultak and Mull Head on East Mainland (Fig. 1). Results of this programme have been reported for

Figure 1. Map of Orkney showing location of study colonies.

1976-81 (Wanless *et al.* 1982ab) and 1976-85 (Benn *et al.* 1987). This paper updates information on population trends in sample plots at these colonies up to 1997 and also includes a summary of the results of various whole-colony counts made during the same period.

While information on population trends may indicate long-term effects of environmental change on seabirds, year-to-year variation in breeding success is potentially a more sensitive indicator of sudden environmental change. Annual monitoring of Common Guillemot breeding success was initiated in 1983 and Kittiwakes were included from the following year. In 1989, this aspect of the Orkney seabird monitoring programme was considerably expanded and Northern Fulmars were added. This work has since continued on an annual basis. The results obtained are examined here in relation both to population trends in

Orkney and to the breeding performance of the same species in other regions of Britain.

METHODS

Sample plot counts

At each of the five colonies selected for monitoring in 1976 (Fig. 1), the boundaries of between four and seven sample plots were marked onto photographic prints (Jones 1978). These plots were selected for ease and safety of counting and to include as wide a range of cliff types as possible rather than at random, as is now recommended for population monitoring (Walsh *et al.* 1995). Following the recommendations of Wanless *et al.* (1982a), counting was discontinued at several plots in 1982 and 1983 and new plots were added in 1983 and 1984; three auk monitoring plots at Costa Head and Marwick Head, in which count accuracy was poor, were replaced by four smaller plots typically holding 100-300 Common Guillemots (Wanless *et al.* 1983), and a plot at Marwick Head, where winter gales had caused substantial topographical changes, was replaced by several more plots (Tasker 1983; Griffiths 1984). These changes rendered the plot series more representative and improved count accuracy while retaining most of the original plots, thus enabling long-term comparisons to be made. The proportions of the total numbers of each species visible from land at each colony that were contained within the monitoring plots in 1985/86 are shown in Table 1. The same plots have been counted since 1985, with the exception of one plot at Marwick Head in which Kittiwakes were not counted in 1985. Counts were made annually up to and including 1988 and thereafter triennially (i.e. in 1991, 1994 and 1997). Full details of individual plots are given in Jones (1978), Wanless *et al.* (1982a) and Tasker (1983).

Count units used for the plots are individual birds for Guillemots, Razorbills and Fulmars (Wanless *et al.* 1982b) and apparently occupied nests for Kittiwakes. These count units are those generally adopted for counting these species in Britain and Ireland, with the exception of Fulmars where the recommended unit is apparently occupied sites (Walsh *et al.* 1995). Individual Fulmars were counted because of difficulty in identifying apparently occupied sites on Orkney cliffs; inter-observer variation in counts was found to be less for individual birds than for counts of apparently occupied sites (Wanless *et al.* 1982b). All counts used in the analyses reported here were made in June in winds of Beaufort force 4 or less and never in fog or heavy rain. Counts of auks were made between 06:00h and 15:30h GMT from 1-22 June, generally before the first chicks fledge. These restrictions on dates, times and weather conditions were adopted to minimise day to day variability in counts, particularly of auks (Walsh *et al.* 1995). Plots were normally counted a minimum of five times each year from fixed positions that ensured consistency in viewing angles. Where possible, counts at each colony were carried out at approximately the same time of day in each year (Costa Head 06:00-10:00h, Gultak 10:30-14:30h, Marwick Head 11:00-15:00h, Mull Head 11:30-15:30h and Row Head 07:30-11:30h) in order to further minimise potential variability (Harris *et al.* 1983). There were some exceptions to this, particularly in 1986 and 1997 when some counts were carried out later at Costa Head and earlier at Gultak, Marwick Head, and Row Head. In addition, the Gultak plots were counted later in 1980 and one count at Row Head in 1997 was made in the afternoon.

Following the methods adopted by Benn *et al.* (1987), counts for each year and species were summed across the plots in each colony for those days in which all plots were counted and mean and standard deviations calculated. The statistical significance of changes between consecutive years was assessed using two-tailed *t*-tests applied only to those plots common to both years. In order to examine long-term trends, an index was established for each species at each colony using 1976 as the baseline (index value 100). Colony index values for subsequent years were calculated using the percentage change over all plots common to adjacent years. An overall index for Mainland Orkney was also calculated for each species, using all common plots between years, regardless of colony. The overall Mainland Orkney indices for the period 1976 to 1985 reported here are from Benn & Tasker (1985). Indices for individual colonies in this period, although not published, were also derived from Benn and Tasker (1985). Subsequent colony and combined indices were calculated as described above by comparison with the 1985 counts and indices. Average annual rates of population change were calculated by linear regression of the logarithms of index values on year. The regression slope is equivalent to the average annual rate of increase or decrease and its significance (i.e. probability of differing from zero) can be assessed using a *t*-test (Wilkinson 1990).

Whole-colony counts

In addition to the sample plot counts described above, a number of whole-colony counts have been undertaken at the five study colonies since 1976. All species were counted at Marwick Head in 1979 (Planterose 1979); all except Fulmar at all five colonies in 1981 (Wanless *et al.* 1982a); Kittiwakes at Marwick Head in 1983 (Tasker 1983); all species at all colonies in 1985 or 1986 (Benn & Tasker 1985, Beveridge 1986); all species at all colonies, except Fulmar and auks at Costa Head, in 1991 (JNCC unpublished data); and Kittiwakes at all colonies in both 1994 and 1997 (JNCC unpublished data). All of these, with the exception of the 1979 count at Marwick Head, were made from land only and so exclude sections of the colonies visible only from the sea. Most of these counts were made applying the same date, time and weather criteria as for the plot counts; notable exceptions are detailed in the Results.

Breeding success

Kittiwake Between 1986 and 1988, breeding success of Kittiwakes was estimated in the population monitoring plots by dividing the total number of chicks present in mid-July (prior to first fledging) by the peak count of apparently occupied nests in the plot in June. Such low intensity methods typically overestimate actual breeding success by *c.* 10-20% (Walsh *et al.* 1995).

More intensive monitoring, following the progress of individually identified nests recorded on photographs from early incubation to near fledging, was initiated in two study plots at Marwick Head in 1984. Up to 1986, those chicks known to have reached at least 30 days old when last observed were assumed to have fledged. This tends to overestimate breeding success as fledging does not occur until chicks are 35 or more days old (Walsh *et al.* 1995). From 1987 onwards, only chicks known to be over 35 days old, or assessed to be so on the basis of plumage characteristics (Walsh *et al.* 1995), were assumed to have fledged. Since 1989, a much larger-scale intensive monitoring scheme, using a total of 15 plots in the five colonies (with the exception of Costa Head from 1992 to 1997 inclusive), has been undertaken each year. Details of original plot selection are given in Ribbands (1990). Breeding success for each colony is herein expressed as the mean of the individual plot figures (Walsh *et al.* 1995).

Northern Fulmar Monitoring of Fulmar annual breeding success was initiated in 11 sample plots at Costa Head, Mull Head and Gultak in 1989 (Ribbands 1990) using standard methods recommended by Walsh *et al.* (1995). In 1989 and 1991, a single plot was also monitored at Row Head. Two or three visits were made to each plot between late May and mid-June to identify apparently occupied breeding sites. These sites were checked again on one or more visits in August and for each plot breeding success was estimated as number of large young present per regularly occupied site. As with Kittiwakes, breeding success of the colony is expressed as the mean of all individual plots (Walsh *et al.* 1995).

Common Guillemot Guillemot breeding success has been monitored annually, with the exception of 1992, in single plots at Marwick Head since 1983 and at Mull Head since 1989. A single plot was also monitored at Row Head in 1989 and 1991. Monitoring breeding success of Guillemots is difficult as no nest is constructed and both eggs and chicks may be difficult to see. A minimum of three visits were made to each plot during the late incubation period to identify 'active' sites definitely occupied by breeding pairs, and additional 'regular' sites at which pairs may have failed earlier in the season (see Walsh *et al.* 1995 for definitions). These sites were then checked at intervals of no more than two days during the chick period. Average breeding success is defined as the number of

Table 1. Proportions of Orkney Common Guillemots, Razorbills, Northern Fulmars, and Kittiwakes visible from land that were within population monitoring plots in 1985 or 1986.

	Common Guillemot (ind)	Razorbill (ind)	Northern Fulmar (ind)	Kittiwake (nests)
Mull Head 1985				
count	1171	125	312	1066
% in plots	80.2	52.0	44.2	65.0
Gultak 1985				
count	1799	470	945	522
% in plots	15.1	39.8	27.2	34.3
Row Head 1985				
count	6103	142	256	2212
% in plots	12.6	10.6	12.5	16.4
Costa Head 1985				
count	7492	673	2548	1652
% in plots	22.7	19.4	7.8	13.7
Marwick Head 1986				
count	22 320	948	1045	3704
% in plots	8.5	9.1	2.1	14.8
All colonies 1985/86				
count	38 885	2358	5106	9156
% in plots	14.4	20.5	12.7	21.8

chicks reaching 15 or more days old when last seen per 'active' plus 'regular' site (Walsh *et al.* 1995).

RESULTS

Population trends in sample plots 1976-97 and comparisons with whole-colony counts

Common Guillemot Changes in Guillemot population indices in monitoring plots for all colonies combined are shown in Fig. 2. Between 1976 and 1981, numbers increased steadily at an average rate of 7.8% *per annum* (t = 11.606, df = 4, P < 0.001) before declining at 3.1% p.a. in the period to 1986 (t = 4.343, df = 4, P < 0.05). From 1986, numbers again increased, although with some fluctuation, at an average rate of 1.6% p.a. (t = 5.213, df = 4, P < 0.01); the index value in 1997 was slightly greater than 50% higher than in 1976.

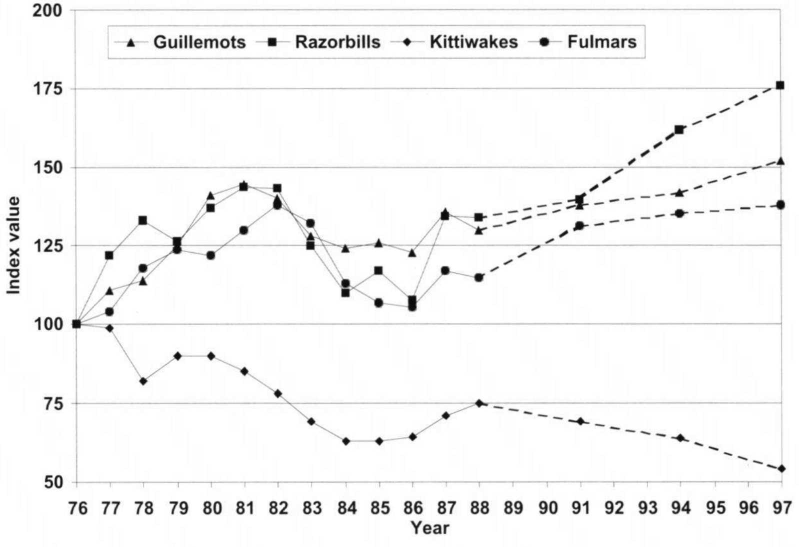
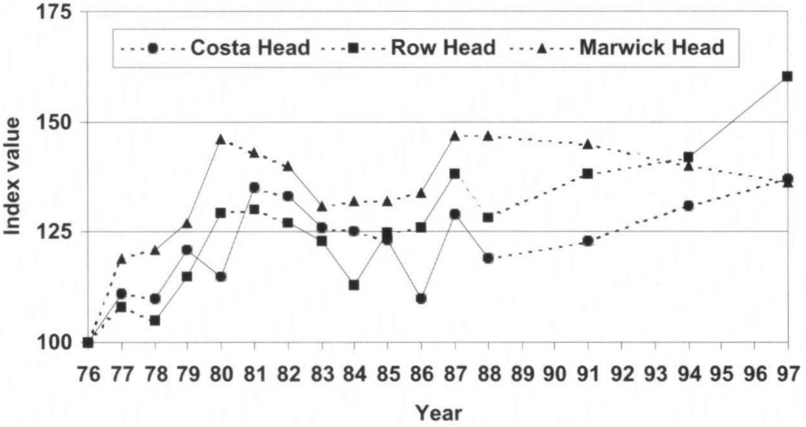


Figure 2. Population indices for individual Common Guillemots, Razorbills and Northern Fulmars and for Kittiwake nests in sample plots across all colonies combined. 1976–97. Broken lines indicate non-annual counts.

The pattern of changes in numbers of Guillemots in sample plots in individual colonies (Fig. 3) is broadly similar to that for all colonies combined. Numbers fell significantly at Row Head in 1984 and at Costa Head in 1986, in contrast to the remaining colonies where numbers were relatively stable between 1983 and 1986. More recently, in the ten years following 1988, numbers in plots at Marwick Head, by far the largest colony (Table 1), declined overall by 7.8% while those at Gultak fluctuated with an overall increase of just 8.6%. These figures compare with a combined increase of 32.2% at the other three colonies. The potentially large variations in numbers of Guillemots attending breeding colonies from day to day, in combination with the often very high densities of birds present, greatly affect the accuracy of the Guillemot population estimates based on single counts. Indeed, the use of multiple counts of sample plots, which enables measures of variability in attendance to be attached to sample population means, was devised specifically to overcome the inherent difficulties in quantifying Guillemot population trends (Harris *et al.* 1983). However, while plot counts are preferred to single whole-colony counts for year to year population monitoring, it is also recommended that whole-colony counts are undertaken periodically as a check on whether colonies appear to be expanding or contracting (Walsh *et al.* 1995).



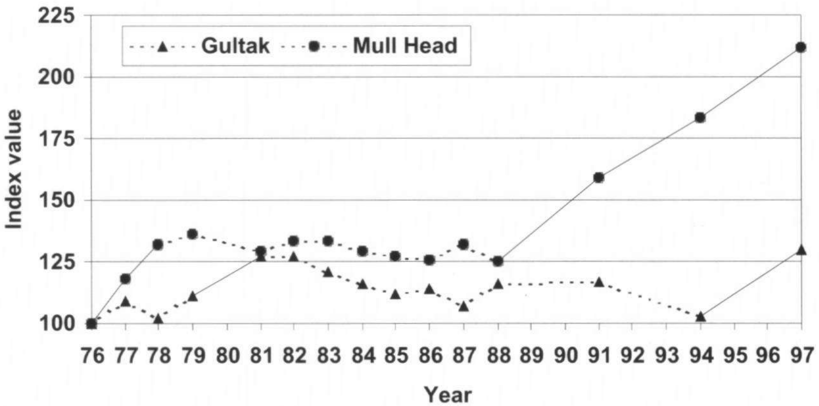


Figure 3. Colony population indices for individual Common Guillemots in sample plots, 1976-97. Solid lines indicate that mean numbers in all plots combined differed significantly (P< 0.05, two- tailed t-test) between the two linked counts and dotted lines indicate no significant change. In some instances counts were made at intervals of more than one year and that annual changes in the intervening period are unknown. a) West Mainland colonies; b) East Mainland colonies.

Table 2. Comparable land-based whole-colony counts for Orkney Common Guillemots (individual birds) and comparison of changes in whole colony counts (% WCC = % change from previous highest directly comparable count) and mean plot counts (% MPC = % change in plot counts over same period).

	1979[a]	1981[b]	1985[d]	1986[e]	1991[f]
Marwick Head					
All sections	27 715	-		22 320	30 854
Count positions 1-11 only	27 225	17 865		21 730	
% WCC		-34.4	-	+21.6	+38.2
% MPC (see note 1)		(+13)	-	(-6)	+8.0
Row Head (see note 2)	-	6921	6 103		8271
% WCC			-11.8		+35.5
% MPC (see note 1)			-6.0		+11.1
Costa Head (see note 3)		7504+	6857 - 7492		
% WCC			≥ -0.2 ≤ -8.6		
% MPC (see note 1)			-10.8		
Gultak			1799		2486
% WCC					+38.2
% MPC (see note 1)					+4.7
Mull Head	-	1390	1171	-	1593
% MPC (see note 1)			-3.6		+25.1

Notes to Tables 2-5

(1) Changes in plot means for 1981-85 are those published in Benn *et al.* (1987); those for 1991-97 are JNCC (unpublished) and those in parentheses for other years are approximate, based on percentage changes in plot indices derived from Benn & Tasker 1985. Figures in italics indicate that the plots held 50 or fewer birds.

(2) Some of the counts shown for Row Head in 1985 differ from those published in Benn & Tasker (1985) as examination of the original field data (held by JNCC) revealed some tallying errors.

(3) The Costa Head count in 1981 (Wanless *et al.* 1982a) may have excluded some sections (First and Second Geos (Benn & Tasker 1985) at the west end of the colony that were counted in later years. Hence, the 1981 figures are minimum estimates while the 1985 figures are given as a range excluding and including the areas possibly missed in 1981.

(4) Highest directly comparable counts at Marwick Head are sums of all actual land-based counts (i.e. excluding estimates for missed sections or sections not visible from land) that are directly comparable between 1991 and 1994 and between 1994 and 1997. These include sections of cliff visible from land that were not located in earlier counts (JNCC unpublished data).

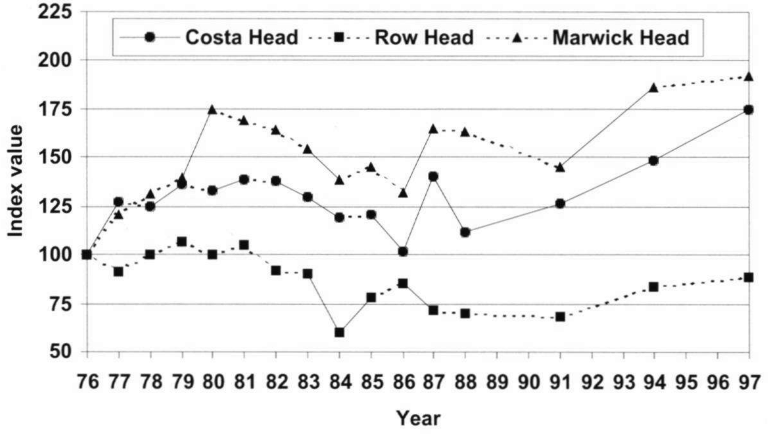
(5) Parts of Costa Head in 1997 were not counted until 4 July following a storm that destroyed some Kittiwake nests present in June. For these sections, a correction factor was applied based on percentage losses of nests in previously counted sections over the intervening period (JNCC unpublished data).

It should be further noted that the whole-colony counts shown in Tables 2-5 are not equivalent to actual numbers of birds as some sections of the cliffs are not visible from land. Sources: a) Planterose 1979; b) Wanless *et al.* 1982a; c) Tasker 1983; d) Benn & Tasker 1985 (and see note 2); e) Beveridge 1986; f) JNCC unpublished data.

There have been relatively few whole-colony counts of Guillemots at the Orkney Mainland study colonies since 1976 against which to compare the plot results. In addition, there is some uncertainty as to the coverage of the Costa Head and Gultak colonies in 1981: maps in Wanless *et al.* (1982a) indicate that some sections that were counted in later years (Benn & Tasker 1985) may have been excluded in 1981. This renders direct comparisons between the 1981 and 1985 counts at these colonies difficult. Those whole-colony counts that can be compared directly are summarised in Table 2, alongside changes in plot counts for the same periods. In most cases there is agreement as to the direction of changes in numbers as indicated by whole-colony versus sample plot counts, although the magnitude of changes in plot counts is generally less than that indicated by whole-colony comparisons. However, at Marwick Head, there is disagreement between the plot and whole colony counts as to the direction of population changes between 1979 and 1986. This may in part reflect the low proportion of the whole population contained within monitoring plots at this colony (Table 1), although even at Mull Head, where more than 80% of the population are contained within sample plots, there is incomplete agreement between plot and whole-colony counts. In addition, the 1981 counts at Marwick Head were carried out very rapidly (over just five hours on two days, compared with in excess of 20 hours over 11 days in 1979) and were not made on currently recommended dates and times for Guillemots (Wanless *et al.* 1982a, Planterose 1979).

Razorbill The overall pattern of change in Razorbill numbers in sample plots across all colonies combined is very similar to that observed for Guillemots (Fig. 2). Between 1976 and 1981, numbers increased at an average rate of 6.2% p.a. ($t = 3.754$, df = 4, $P < 0.05$), although there was an overall decrease between 1978 and 1979 that mainly reflected declines at the East Mainland colonies of Gultak and Mull Head (Fig. 4b). From 1981 to 1986, numbers declined at 6.1% p.a. ($t = 4.825$, df = 4, $P < 0.01$) but thereafter increased again, at an average annual rate of 3.8% ($t = 4.743$, df = 4, $P < 0.01$); the overall index value in 1997 was around 75% higher than the 1976 baseline.

The patterns of change in individual colonies (Fig. 4) are generally similar to that for all colonies combined. The overall increase between 1976 and 1997 was greater at the East Mainland colonies of Gultak and Mull Head (Fig. 4b), where index values more than doubled, than at the three West Mainland sites (Fig. 4a). The main exception to the overall trend was Row Head, where overall numbers declined since 1976. However, the very low numbers of Razorbills monitored at this small colony (Table 1) mean that minor variation in



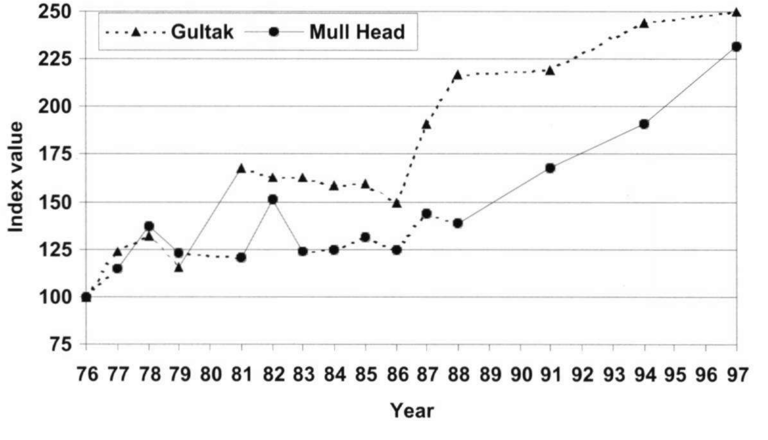


Figure 4. Colony population indices for individual Razorbills in sample plots, 1976-97. See Fig. 3 for conventions.

the numbers of birds attending the cliffs can have a marked effect on annual plot means.

Table 3 summarises directly comparable whole-colony counts for Razorbills and compares changes in these with those observed in sample plot counts over the same periods. No comprehensive counts of Razorbills were made at Marwick Head in either 1979 (Planterose 1979) or 1981 (Wanless *et al.*

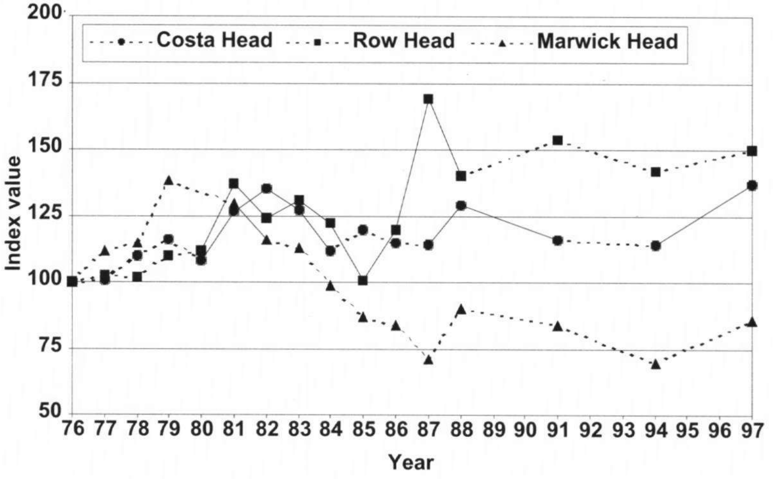
1982a), thereby preventing comparison with later counts. Generally, plot counts and whole-colony counts are in broad agreement with respect to the direction and approximate magnitude of changes in numbers over comparable periods; an exception is Row Head, where plot counts indicate a decline between 1985 and 1991, while whole-colony counts increased, but this again could reflect the very small numbers of Razorbills in the sample plots at this colony.

Table 3. Comparable land-based whole-colony counts for Orkney Razorbills (individual birds) and comparison of changes in whole colony counts (% WCC) and mean plot counts (% MPC). See Table 2 for conventions.

Colony	1981[b]	1985[d]	1986[e]	1991[f]
Marwick Head			948	1,088
% WCC				+14.8
% MPC (see note 1)				+10.3
Row Head (see note 2)	189	142		162
% WCC		-24.9		+14.1
% MPC (see note 1)		*-30.0*		*-12.8*
Costa Head (see note 3)	771+	557 – 673		
% WCC		≥-12.7 - ≤-27.8		
% MPC (see note 1)		-20.0		
Gultak		470		760
% WCC				+61.7
% MPC (see note 1)				+37.0
Mull Head	84+(incompl)	125	-	141
% WCC		(≤ +48.8)		+12.8
% MPC (see note 1)		+13.2		+28.4

Northern Fulmar Numbers of Fulmars in sample plots also show three distinct phases of change (Fig. 2). From 1976 to 1982, numbers increased on average by 5.3% p.a. (t = 7.979, df = 5, P < 0.001), followed by a decline averaging 7.1% p.a. (t = 5.424, df = 3, P < 0.05) to 1986. From 1986-97 numbers again increased, by 2.3% p.a. (t = 5.216, df = 4, P < 0.01); the overall index value in 1997 was nearly 40% higher than the 1976 baseline.

Patterns of change at individual colonies (Fig. 5) have been rather more variable for Fulmars than for Guillemots and Razorbills (Figs. 3 and 4). At the largest colony, Costa Head, numbers in sample plots increased by only 5.5% overall from 1988-97, compared with 20.0% across all colonies combined in the same period and there was a significant decline between 1988 and 1991. At Row Head, a marked increase between 1985 and 1987 was followed by a decline to 1988, after which numbers stabilised. However, as with Razorbills, actual numbers of Fulmars monitored at this colony are small (Table 1) and so counts are likely to fluctuate greatly from year to year. The same is also true of Marwick Head, the only colony at which Fulmar numbers in sample plots have declined overall since 1976.



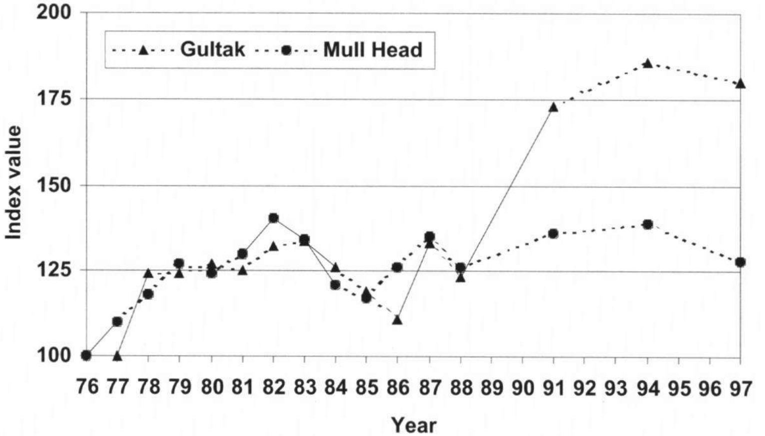


Figure 5. Colony population indices for individual Northern Fulmars in sample plots, 1976-97. See Fig. 3 for conventions.

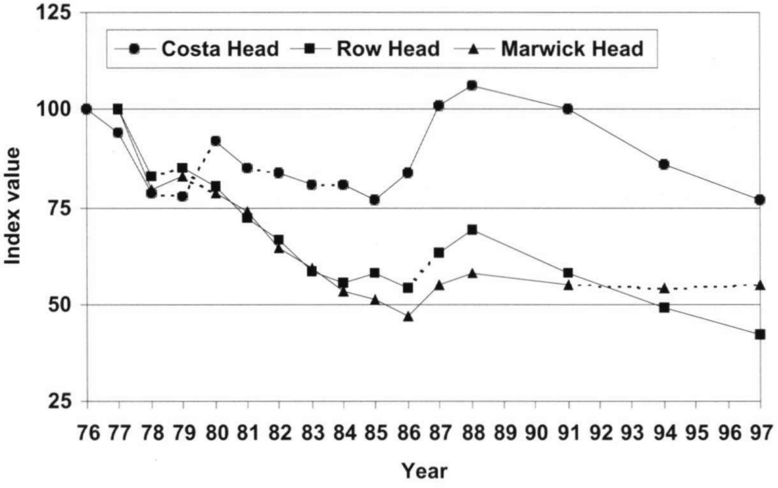
Table 4. Comparable land-based whole-colony counts for Orkney Northern Fulmars (individual birds) and comparison of changes in whole colony counts (% WCC) and mean plot counts (% MPC). See Table 2 for conventions.

Colony	1985[d]	1986[e]	1991[f]
Marwick Head		1045	977
% WCC			-6.5
% MPC (see note 1)			-0.8
Row Head (see note 2)	256		330
% WCC			+28.9
% MPC (see note 1)			+53.5
Gultak	945		1533
% WCC			+62.2
% MPC (see note 1)			+45.0
Mull Head	312	-	361
% WCC			+15.7
% MPC (see note 1)			+16.0

There are very few whole-colony counts of Fulmars available for comparison with the plot counts. Fulmars were not counted in 1981, and the 1991 counts did not include Costa Head. In addition, the 1979 count at Marwick Head was incomplete, with those birds interspersed with Kittiwakes on the lower ledges having been overlooked (Planterose 1979). However, where direct comparisons can be made, there is generally fairly good agreement as to the direction and approximate scale of change (Table 4).

Kittiwake The pattern of change observed in Kittiwake plot counts between 1976 and 1997 is very different from the other three species (Fig. 2). Numbers of apparently occupied nests declined on average by 2.5% p.a. ($t = 6.032$, df = 14, $P < 0.001$); the 1997 index value is slightly greater than 50% of the 1976 baseline. The same basic pattern was observed across all five colonies (Fig. 6); decline was proportionately greatest at Gultak (the smallest colony) and Row Head, and least at the north coast colonies of Costa Head and Mull Head. At Marwick Head, the largest colony, numbers apparently stabilised in the sample plots between 1987 and 1997 following a very rapid decline to 1986.

Changes in Kittiwake plot counts and whole-colony counts are shown in Table 5. Generally, there is good agreement between these counts in the direction and scale of changes in numbers of Kittiwake nests at the five colonies. Closest



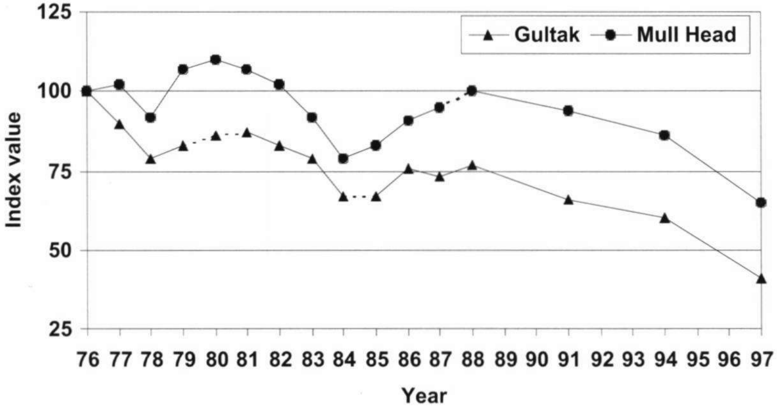


Figure 6. Colony population indices for individual Kittiwakes in sample plots, 1976-97. See Fig. 3 for conventions.

Table 5. Comparable land-based whole-colony counts for Kittiwakes (apparently occupied nests) and comparison of changes in whole colony counts (% WCC) and mean plot counts (% MPC). See Table 2 for conventions.

Colony	1979[a]	1981[b]	1983[c]	1985[d]	1986[e]	1991[f]	1994[f]	1997[f]
Marwick Head								
all sections	6945	-	4398		3704	5252	4589	4543
count positions 1-11 only	6436	3313	4113					
highest directly comparable (see note 4)						5698	5004	
highest directly comparable (see note 4)							4873	5102
% WCC		-48.5	+24.1		-15.8	+41.8	-12.2	+4.7
% MPC (see note 1)		(-11)	(-20)		(-20)	+16.7	-1.2	+0.9
Row Head (see note 2)	-	2549		2212		2606	2350	2099
% WCC				-13.2		+17.8	-9.8	-10.7
% MPC (see note 1)				-15.2		-0.7	-15.5	-13.8
Costa Head (see notes 3 & 5)		1796+		1501-1652		2656	2274	*c.* 2038
% WCC				$\geq$ -8.0 - $\leq$ -16.4		+60.8	-14.4	- *c.* 10
% MPC (see note 1)				-2.0		+30.4	-14.5	-9.9
Gultak				522		599	662	415
% WCC						+14.8	+10.5	-37.3
% MPC (see note 1)						-1.5	-9.3	-32.3
Mull Head	-	1392	-	1066	-	1283	1129	791
% WCC				-23.4		+20.4	-12.0	-29.9
% MPC (see note 1)				-26.0		+13.6	-8.3	-24.7

agreement is at Mull Head, where 65% of the total population is included in sample plots (Table 1), but notable exceptions occur at Marwick Head, where plot counts declined significantly between 1981 and 1983 by around 20% (Fig. 6), while whole-colony counts indicated a 24% increase. Similarly, whole-colony counts increased between 1985 and 1991 at Gultak and Row Head, and between 1991 and 1994 at Gultak, while plot counts declined in these periods. Overall, both whole-colony and sample plot counts indicate that there was a substantial decline in the Mainland Orkney Kittiwake breeding population in the 1980s and 1990s. In the period 1991 to 1997, for which the most comprehensive data are available, whole-colony counts indicate a decline of 20.2% and mean plot counts a decline of 21.2% across all five colonies combined.

Breeding success

Common Guillemot Guillemot breeding success data are summarised in Fig. 7. Between 1983 and 1989, monitoring at the Marwick Head plot was very intensive, checks being made daily (Tasker 1983; Griffiths 1994; Benn 1985; Beveridge 1986; Ward 1987; Thomas 1988) or at most every two days (Ribbands 1990) from late May to the end of the fledging period. Thus, the majority of those pairs that laid eggs were probably detected and the data (shown as Marwick Head A, Fig. 7), are roughly equivalent to chicks fledged per 'active' plus 'regular' site (see Methods) in subsequent years.

At Mull Head and Row Head in 1989 and at all colonies in all years from 1990, increased work on other species led to less intensive monitoring of Guillemots, particularly during the early breeding season. In most years, plots were checked only three times in early June to identify 'active' and 'regular' sites. However, in 1991, 1994 and 1997, more visits were made and larger numbers of 'regular' sites were identified, particularly at Mull Head. Consequently, estimates of breeding success per 'active' plus 'regular' site are probably proportionately lower than those for 'active' only sites in these years.

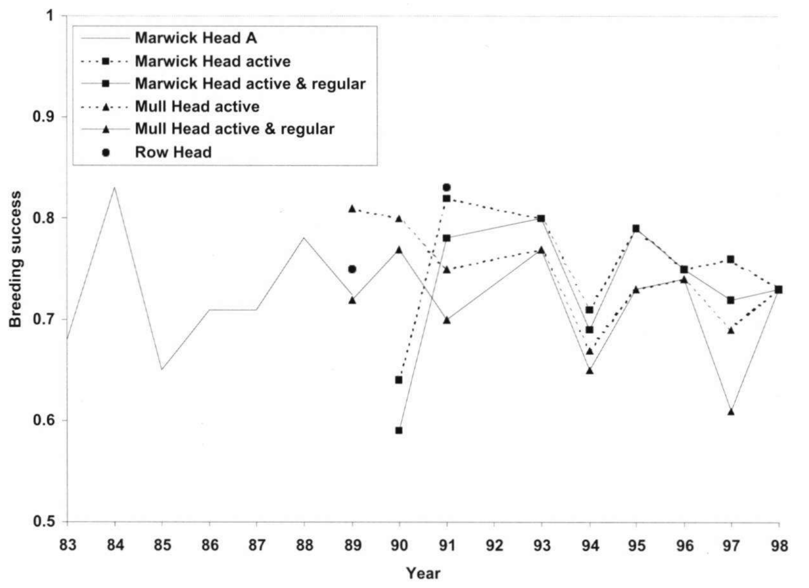


Figure 7. Common Guillemot breeding success (chicks fledged per 'active' plus 'regular' site), 1983-98. See text for explanation of the various data series.

Breeding success of Guillemots typically fluctuated between 0.7 and 0.8 chicks fledged per 'active' plus 'regular' site and in most years was apparently slightly higher at Marwick Head than at Mull Head. There were no apparent trends over time at either site. Mean breeding success was 0.73 ±0.02 SE at Marwick Head for the period 1983-98 (series A to 1989, 'active' plus 'regular' sites from 1990) and 0.71 ±0.02 per 'active' plus 'regular' site at Mull Head for the period 1989-98. These figures are similar to an average of 0.74 ±0.01 measured for between three and 14 colonies in Britain annually between 1986 and 1997 (Thompson *et al.* 1999).

The exceptionally low breeding success recorded at Marwick Head in 1990 (0.59 chicks per 'active' plus 'regular' site) was associated with an unusually late median fledging date and a prolonged spell of strong, mainly westerly winds from late June to mid-July (Crossley 1990). Lower than usual breeding success (as measured both per 'active' and per 'active' plus 'regular' site) was also associated with a late breeding season in 1994 (JNCC, unpublished data). Breeding success was also low at Mull Head in 1997, although the effect was much less marked when 'active' sites only were considered, and may in part be an artefact associated with more frequent checks early in the breeding season (see above).

Northern Fulmar Fulmar breeding success data for the period 1989 to 1998 are summarised in Fig. 8. The 1989 data are not directly comparable with those for subsequent years, as preliminary checks to identify occupied sites were not made until mid-June. Fulmar breeding success in Orkney typically ranged between 0.4 and 0.6 chicks fledged per apparently occupied site and there were no apparent trends over time. In most years, breeding success was highest at Costa Head, the largest colony (1990-98 mean = 0.52 ±0.02) and lowest at Mull Head (1990-98 mean = 0.43 ±0.01) with Gultak being intermediate (1990-98 mean = 0.44 ±0.04). These figures are similar to or greater than the average for 1986-97 of 0.43 ±0.01 as recorded in between 13 and 41 colonies in Britain annually (Thompson *et al.* 1999). The exceptionally low breeding performance at Gultak in 1997 (0.19 chicks per site) was probably due to predation of chicks on the upper grassy slopes by feral cats (K. Thompson, pers. obs.). Mammalian predators may have contributed to low productivity at some of the Mull Head plots in 1994 (JNCC, unpublished data). Breeding success of 0.72 chicks fledged per apparently occupied site at a single small plot at Row Head in 1992 was exceptionally high for this species.

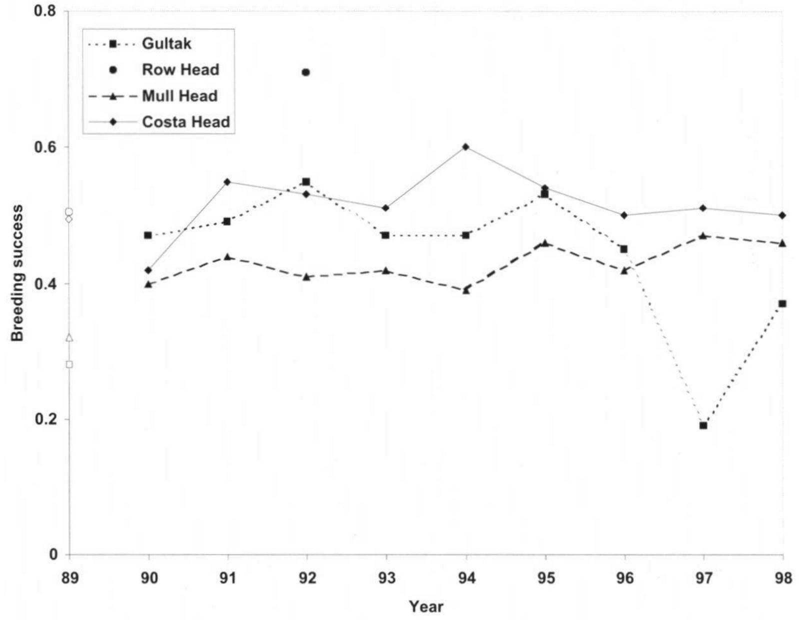
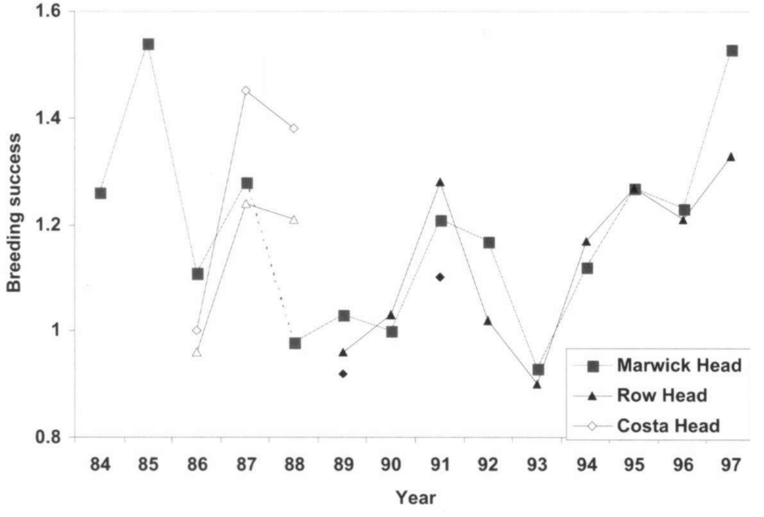


Figure 8. Northern Fulmar breeding success (chicks fledged per apparently occupied site), 1989-98.

Kittiwake Kittiwake breeding success for the period 1984 to 1998 is summarised in Fig. 9. Kittiwakes in Mainland Orkney typically produced about one chick per breeding pair *per annum*, although there is considerable variation in productivity between years and breeding success is generally lower in smaller colonies. Mean productivity for the four colonies monitored regularly by intensive methods, in descending order of colony size are: 1.15 ±0.06 (Marwick Head, 1984-98), 1.13 ±0.05 (Row Head, 1989-98), 1.09 ±0.06 (Mull Head, 1989-98) and 0.88 ±0.08 (Gultak, 1989-98). These figures compare with a Britain and Ireland annual average of 0.73 _0.03 for the period 1986-97 in 30 to 61 colonies. Breeding success at colonies on Mainland Orkney is consistently among the highest recorded throughout Britain and Ireland (Thompson et al. 1999).

Estimated breeding success apparently fluctuated between 1984 and 1986 at the two plots monitored intensively at Marwick Head, but late chick mortality was more likely to be detected in 1984 and 1986 when checks continued until most chicks had fledged. Similarly, the low breeding success in intensively monitored plots at Marwick Head in 1988 reflected late mortality of



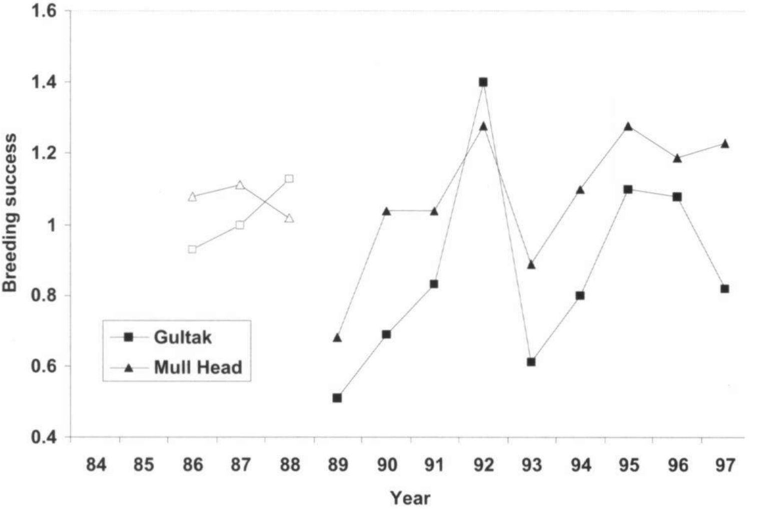
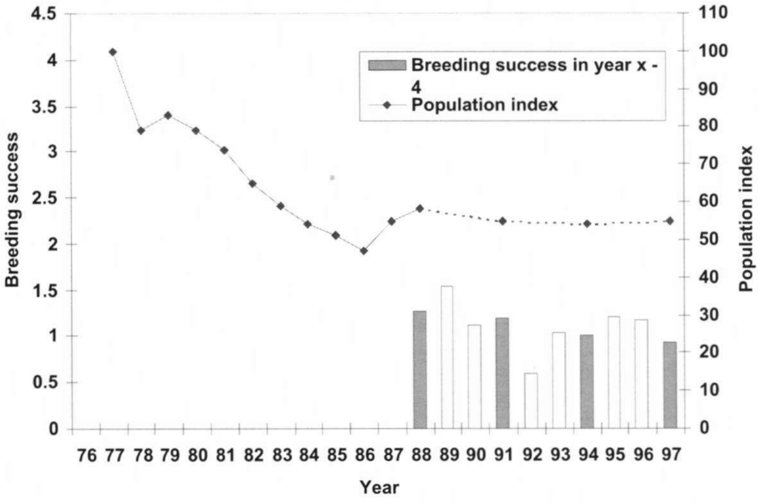


Figure 9. Kittiwake breeding success (chicks fledged per apparently occupied nest), 1984-98. Solid symbols indicate intensive monitoring methods and open symbols indicate low intensity monitoring methods. These two types of data are not directly comparable (see text). a) West Mainland colonies; b) East Mainland colonies.



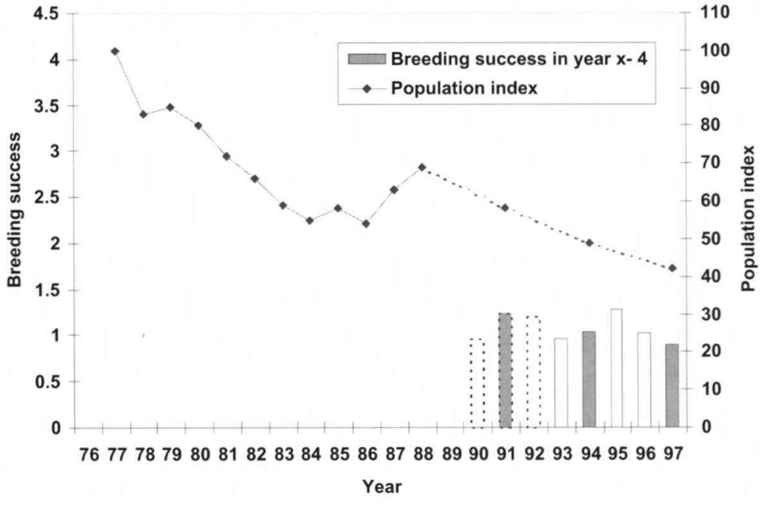
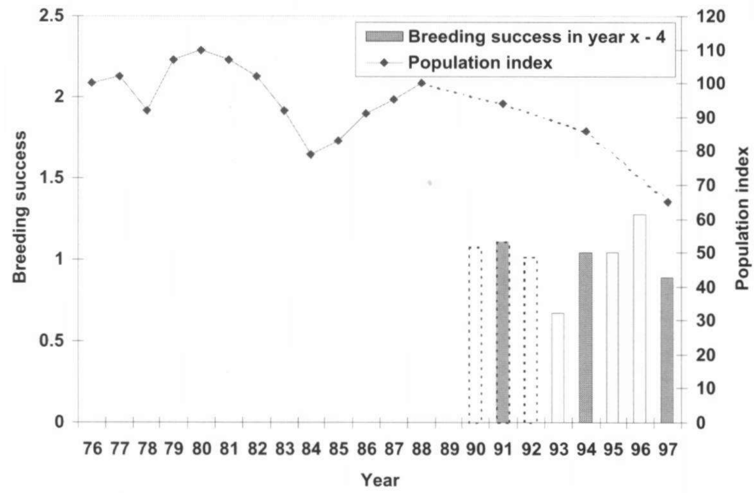


Figure 10 a-b. Kittiwake breeding success in relation to population trends. Bars with solid borders indicate breeding success measured by high intensity methods and bars with broken borders indicate breeding success measured by low intensity methods (which could overestimate success by 10- 20%). Shaded bars indicate breeding success four years prior to years for which population data are available and unshaded bars indicate breeding success for intervening years. a) Marwick Head; b) Row Head.



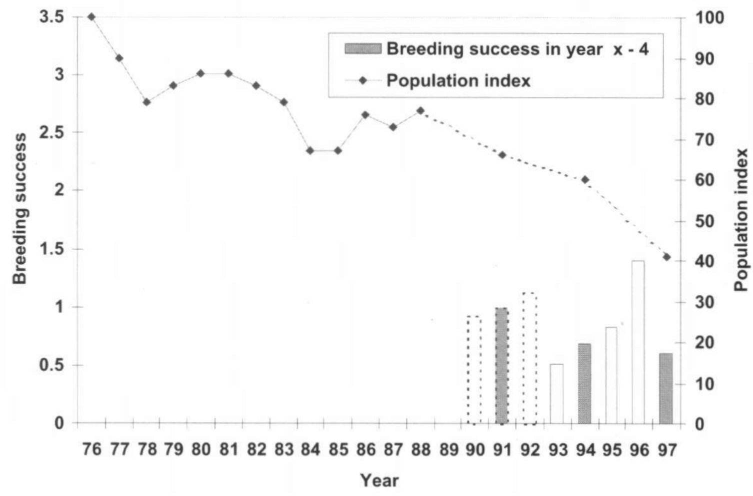


Figure 10 c-d. Kittiwake breeding success in relation to population trends. Bars with solid borders indicate breeding success measured by high intensity methods and bars with broken borders indicate breeding success measured by low intensity methods (which could overestimate success by 10- 20%). Shaded bars indicate breeding success four years prior to years for which population data are available and unshaded bars indicate breeding success for intervening years.c) Mull Head; d) Gultak well-grown chicks that would not have been detected by the less intensive monitoring method used at the other colonies that year. Indeed, at Marwick Head itself in 1988, comparison of counts of chicks in mid-July with peak June nest counts in the population monitoring plots suggested mean breeding success of 1.17 chicks fledged per pair, nearly twice that estimated in the intensively monitored plots. The reason for the very low breeding success at East Mainland colonies (Mull Head and Gultak) in 1989 is not known. Poor breeding performance at all colonies in 1993 was caused by strong winds and heavy rain in late June and early July leading to high mortality among early hatched chicks (Paice 1993).

Given the generally high level of Kittiwake breeding success at Mainland Orkney colonies, the observed decline in Kittiwake populations at these sites is unexpected. Kittiwakes typically first breed at four or five years old (Wooler & Coulson 1977), so it might be expected that any trends in breeding success would be reflected in the size of the breeding population four or more years later. Fig. 10 shows population indices in relation to breeding success four years earlier. Data available for direct comparisons are limited as population monitoring took place only every three years between 1988 and 1997, while productivity monitoring at most colonies began only in 1986. Also, prior to 1989 (shown against 1993 in Fig. 10), monitoring of breeding success at most colonies was by low-intensity methods that are not directly comparable with later years, and which tend to miss any late season mortality, such as observed at Marwick Head in 1988.

However, as illustrated in Figs. 10b-d, there is an indication that falling population indices between 1991, 1994 and 1997 at Row Head, Mull Head and Gultak do reflect declines in breeding success in 1987, 1990 and 1993; no such relationship is apparent for Marwick Head (Fig. 10a). More importantly, it would be expected that a consistent downward trend in breeding success would be needed to drive a population decline, whereas it can be seen that breeding success fluctuated in intervening years.

DISCUSSION

Observed coefficients of variation in plot counts for the period 1976 to 1980 led Wanless *et al.* (1982b) to conclude that, depending on the number of counts made each year, the population monitoring scheme on Mainland Orkney should enable annual changes in numbers of the order of 10-20% for Guillemots, 30-50% for Razorbills, 20-30% for Fulmars and 5-10% for Kittiwakes to be detected. It can be seen in Figs. 3-6 that, indeed, with the exception of the Kittiwake, relatively few year to year changes are statistically significant. However, despite the inherent difficulties in detecting relatively small short-term changes in auk and Fulmar populations, and the possible limitations imposed by non-random selection of plots (discussed in Benn *at al.* 1987) the Orkney monitoring scheme has proved valuable in detecting longer-term trends in seabird populations. Given the long lifespans and deferred sexual maturity of these species, such long-term monitoring is essential for the detection of trends at time-scales appropriate to their population dynamics.

Common Guillemot The overall increase in Guillemot numbers in the Orkney plots between 1976 and 1997 is in line with data from other parts of Britain. Numbers in Britain and Ireland more than doubled between 1969/70 and 1985-87 (Lloyd *et al.* 1991) and since 1986 there have been further highly significant increases in Guillemot numbers in monitoring plots at colonies in a number of regions, including eastern Scotland and Wales (Thompson *et al.* 1999).

This overall increase in numbers in the Orkney plots masks the period of stability or decline recorded at the five colonies in the early 1980s. A similar pattern was observed at a number of other monitored colonies in Scotland at this time (e.g. Isle of May, Canna and Troup Head), although the initial period of increase at these colonies halted one or two years later than observed in Orkney (Lloyd *et al.* 1991). However, at various other colonies throughout Britain (e.g. St Abb's Head, Farne Islands, Berry Head, Skomer and Bardsey) numbers steadily increased during the 1980s (Lloyd *et al.* 1991). In Shetland, where a population monitoring scheme similar to that in Orkney has been running since 1978, an initial increase to a peak in 1982 was followed by a decline to 1990, with particularly steep annual decreases from 1984 to 1985 and from 1989 to 1990. Although numbers recovered somewhat to the late 1990s, the increase was sufficient only to return populations to 1978 baseline levels (Heubeck 1998).

In Orkney, numbers of Guillemots counted in plots have varied considerably between colonies since the last population census in 1985/86 (Lloyd *et al.*. 1991). In particular, at the Marwick Head colony, which alone holds over half of the Guillemots in the five monitored colonies, numbers in plots have remained fairly level. If the overall changes in plot indices for individual colonies between 1986 and 1997 are applied to the 1985/86 land-based counts, the results suggest an overall population increase of 10% to 1997, compared with a 22% increase across all plots combined.

Breeding success of Guillemots in Orkney from 1989-97 was generally similar to the average for this species in Britain, but there have been a few seasons with much lower than usual chick production. Given an average age of first breeding of six or seven years (Harris *et al.*. 1994), it is not yet possible to determine if reduced breeding success in some years of this study will eventually be reflected in breeding numbers.

Razorbill The overall change in Razorbill numbers in the Orkney plots has been similar to, but even more pronounced than that observed in Guillemots, with major increases indicated at all but Row Head, where monitoring effort might be inadequate to detect actual population change. As with Guillemots, the apparent increase in Razorbill populations, particularly in the 1990s, is mirrored in several other regions, including south-east Scotland and Wales (Thompson *et al.* 1999).

The decline in Razorbill numbers in Orkney in the early 1980s and in particular the very marked decreases from 1982 to 1984, may perhaps be associated with a large wreck of this species on Orkney and North Sea coasts in February 1983 (Heubeck *et al.* 1992). However, in this context it should be noted that Guillemot numbers remained fairly stable following a similar scale wreck in Orkney in the winter of 1984/85. In Shetland, Razorbill population trends have been similar to those observed for Guillemots, with a fluctuating decline during the 1980s to around 50% of 1978 baseline levels, thereafter followed by a partial recovery (Heubeck 1998).

Northern Fulmar The general increase in Fulmar numbers in the Mainland Orkney plots accords with trends observed throughout Britain and Ireland between 1969/70 and 1985-87 (Lloyd *et al.* 1991) and subsequently in various regions, including south-east Scotland, north-east England and Wales (Thompson *et al.* 1999). In contrast to Guillemots and Razorbills however, Fulmars have also increased significantly in Shetland since the late 1970s (Heubeck 1998). In Shetland, there are disparities between trends in numbers of individual Fulmars and of apparently occupied sites at annually monitored sites. There is also some evidence to suggest that the numbers of loafing Fulmars attending colonies may be related to food supply (Shetland Oil Terminal Environmental Advisory Group, unpublished data). In the early years of the Orkney monitoring scheme, large discrepancies were noted in the apparent population trends indicated when both individual Fulmars and apparently occupied sites were counted (Wanless *et al.* 1982b). Thus, the decline in counts of individual birds in Orkney in the early 1980s, may not accurately reflect changes in the breeding population. The extent to which the presence of varying proportions of non-breeding adults in colonies may also have influenced the very similar apparent population trends recorded for Guillemots and Razorbills in Orkney is unknown.

Trends in Fulmar population plots, like those of Guillemots, have varied considerably between colonies in Orkney, and caution must be applied when extrapolating from changes in the combined colony index to the population as a whole. If the changes in individual colony indices in the period 1985/86 to 1997 are applied to the 1985/86 land-based counts, an overall population increase of 20% is suggested, in contrast to a 30% increase in the overall index value in the same period. However, monitoring effort at both Row and Marwick Heads may be too low to allow detection of actual change at these colonies.

Fulmar breeding success in Orkney since 1989 has been comparable to or above the mean for Britain as a whole, with localised predation being responsible for the only notable instance of markedly reduced chick production. The species, therefore, appears capable of sustaining its expansion in Orkney.

Kittiwake Both plot counts and whole-colony counts indicate that, in marked contrast to the other three species monitored, Kittiwakes have declined substantially at Mainland Orkney colonies over the past two decades. This decline apparently continues at all colonies, with the possible exception of Marwick Head.

Kittiwake numbers increased in Britain and Ireland from around the beginning of the 20th century to at least 1985-87. There was an overall increase of 22% between 1969/70 and 1985-87 but an estimated 40% decrease in the total Orkney population over the same period (Lloyd *et al.* 1991). Since 1986, trends at regularly monitored colonies in Britain and Ireland have varied considerably between regions and over time (Thompson *et al.* 1999) but overall trends since the mid 1980s are unknown. However, in Shetland, the Kittiwake population decreased by about 50% between 1981 and 1997, with a particularly rapid rate of decline from the late 1980s to mid-1990s. This was attributed to a combination of a series of poor breeding seasons in the late 1980s, affecting subsequent recruitment to the breeding population, and a marked increase in Great Skua *Catharacta skua* predation of both adults and chicks (Heubeck *et al.* 1999).

Great Skuas have been recorded taking Kittiwake eggs, chicks, and juveniles at Orkney colonies (Ward 1987; Ribbands 1990; K. Thompson pers. obs.). However, there is no evidence to suggest a recent marked increase in Great Skua predation on Orkney seabirds, which in Shetland appeared to be prompted by a reduction in sandeel availability in the mid-1980s (Hamer *et al.* 1991). In addition, in contrast to the major concentrations of many hundreds of pairs of breeding Great Skuas found immediately adjacent to some Kittiwake colonies in Shetland (Heubeck *et al.* 1997), a total of only 25 pairs bred on Mainland Orkney at the last census in 1992 (Meek *et al.* 1994). Of these, only three (two at Mull Head and one at Gultak) were close to the Kittiwake colonies (RSPB, unpublished data). It seems highly unlikely, then, that predation by Great Skuas was responsible for the observed decline of the Kittiwake population on Orkney Mainland.

At the Orkney Mainland colonies, Kittiwake breeding success has been higher than the average for Britain and Ireland in all years since intensive monitoring began in the mid-1980s (Thompson *et al.* 1999). The most recent phase of the population decline in Orkney is not associated with any overall falling trend in breeding success, as has been documented for the Isle of May and other colonies along the coast of south-east Scotland and north-east England since 1986 (Harris & Wanless 1997). The complete breeding failures in Shetland in the late 1980s and early 1990s, linked to reduced availability of sandeels (Hamer *et al.* 1993), and the more recent poor breeding seasons in Shetland (Thompson *et al.* 1999) have also not been paralleled at the Orkney colonies. However, while Kittiwake breeding success as indicated by fledging is generally high at the Orkney Mainland colonies, beached bird surveys indicate that in some years large numbers of young Kittiwakes die shortly after fledging (RSPB 1978-98). Exceptionally high levels of post-fledging mortality appeared to occur in 1976 and 1977; the number of dead juveniles found along West Mainland beaches being equivalent to between 6% and 7% of the combined breeding populations at Marwick Head and Row Head (Planterose 1979; Wanless *et al.* 1982a). In addition, higher than average densities were also found in 1978 (no data are available for 1979). It is difficult to assess the actual impact of post-fledging mortality on the Orkney Mainland Kittiwake population because the proportion of juvenile Kittiwakes that die and are subsequently detected on beached bird surveys is unknown and is potentially highly variable. However, it is noteworthy that the sharp decline in the Kittiwake breeding population between 1980 and 1984 occurred at the time when the mid to late 1970s cohorts would have been reaching maturity.

Since 1980, incidences of exceptional post-fledging mortality, as indicated by the beached bird survey data, have been sporadic and apparently less severe than those observed in the late 1970s. Given the consistently high average breeding success recorded since monitoring began in 1984, it seems unlikely that such mortality alone could explain the further decline in the Kittiwake population observed since 1988. The disparity between observed population trends and breeding success suggests either that adult or immature survival rates are lower than required to sustain the population, even at the high breeding success recorded, and/or that there is net emigration of Kittiwakes from Orkney Mainland to other colonies.

No data are available on winter survival rates of adults or on recruitment rates of Kittiwakes in Orkney; measurement of these parameters requires very intensive annual monitoring of individually colour-ringed birds (Harris & Calladine 1993). Heubeck *et al.* (1999) noted the contrasting population trends among Kittiwakes in the late 1980s, when a period of population growth in Orkney (Fig. 2) coincided with rapidly decreasing populations in Shetland and suggested that birds might have emigrated from Shetland to Orkney. However, given the more recent decline in the Orkney Kittiwake population despite high breeding success, the possibility also exists of movements in the opposite direction. Recoveries of ringed Kittiwakes from colonies in eastern Britain have shown that while adults are generally faithful to their breeding colony, there is considerable emigration of young birds away from their natal colonies, including one recovery as an adult in Shetland of a bird fledged from the Isle of May. Fewer than 40% of young Kittiwakes eventually return to breed at their natal colony and some 20% may eventually breed in colonies over 400 km distant (Coulson & Nève de Mévergnies 1992). Hence, emigration of Orkney fledglings to Shetland might occur and in this context the observation of an apparent influx of over 1000 juvenile Kittiwakes into Yell in Shetland in August 1997 (Scalter 1998), following a very poor breeding season in Shetland itself, is of interest. A ringing study designed to assess the scale of any movement of Kittiwakes away from Orkney would be valuable, as would the inclusion in the Orkney monitoring programme of rigorous assessments of post-fledging Kittiwake mortality and the effect of Great Skua predation on Kittiwake numbers.

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SAMENVATTING

POPULATIEONTWIKKELINGEN EN BROEDSUCCES VAN ZEEVOGELS NESTELEND OP DE ORKNEY EILANDEN, 1976-98

Op de Orkney Eilanden worden populatieontwikkelingen van de Noordse Stormvogel Fulmarus glacialis, *de Drieteenmeeuw* Rissa tridactyla, *Zeekoeten* Uria aalge *en Alken* Alca torda *sinds 1976 in vijf kolonies in zogenaamde 'study plots' gevolgd. Daarnaast werden deze kolonies ook af en toe integraal geteld. De aantallen Noordse Stormvogels, Zeekoeten en Alken die in de broedtijd in deze kolonies aanwezig waren, zijn tussen 1976 en 1997 toegenomen. Toch werd voor elk van deze soorten in het begin van de jaren tachtig een periode van neergang geconstateerd en werden verschillen gevonden in de mate van toename (of zelfs afname) tussen verschillende delen van de kolonies. In tegenstelling tot deze drie succesvolle soorten is de populatie Drieteenmeeuwen gemiddeld met 2.5% per jaar afgenomen, waarbij de mate van afname omgekeerd evenredig was aan de koloniegrootte. Het broedsucces van de Noordse Stormvogel, de Drieteenmeeuw en de Zeekoet werd gevolgd vanaf het midden van de jaren tachtig. Het broedsucces van Noordse Stormvogel en Zeekoet was in de meeste jaren vrijwel net zo hoog, of zelfs iets hoger dan het nationale gemiddelde. Paradoxaal genoeg was ook het broedsucces van de Drieteenmeeuw de laatste 10-15 jaar over het algemeen zeer hoog. Aangenomen wordt dat grote sterfte na het uitvliegen, zoals dat ook wel is gezien aan het eind van de jaren zeventig, deze paradox deels verklaart. In het stuk wordt echter geen eenduidige verklaring gegeven voor de gestage afname van de populatie op de Orkney Eilanden.*

REFERENCES

Benn S. 1985. Surveillance of cliff-nesting seabirds in Orkney, 1985. Nature Conservancy Council Chief Scientist Directorate Contract Report No. 597.

Benn S. & Tasker M.L. 1985 Surveillance of cliff-nesting seabirds in Orkney, 1976-1985. Nature Conservancy Council Chief Scientist Directorate Report No.608.

Benn S., Tasker M. & Reid A. 1987. Changes in numbers of cliff-nesting seabirds on Orkney, 1976-85. Seabird: 10: 51-57.

Beveridge F. 1986. Surveillance of cliff-nesting seabirds in Orkney, 1986 Nature Conservancy Council Chief Scientist Directorate Contract Report No.662.

Coulson J.C. & Nève de Mévergnies G. 1992. Where do young Kittiwakes *Rissa tridactyla* breed, philopatry or dispersal? Ardea 80: 186-197.

Crossley J. 1990. Monitoring of breeding success of cliff-nesting seabirds in Orkney in 1990. Nature Conservancy Council Chief Scientist Directorate Report No. 1163.

Griffiths A.M. 1984. Surveillance of cliff-nesting seabirds in Orkney, 1984. Nature Conservancy Council Chief Scientist Directorate Report No.550.

Hamer K.C., Furness R.W. & Caldow R.W.G. 1991. The effects of changes in food availability on the breeding ecology of Great Skuas *Catharacta skua* in Shetland. J. Zool. Lond., 223: 175-188.

Hamer K.C., Monaghan P., Uttley J.D., Walton P. & Burns M.D. 1993. The influence of food supply on the breeding ecology of Kittiwakes *Rissa tridactyla* in Shetland. Ibis: 135: 255-263.

Harris M.P. & Calladine J. 1993. A check on the efficiency of finding colour-ringed Kittiwakes *Rissa tridactyla*. Ringing & Migration 14: 113-116.

Harris M.P. & Wanless S. 1997. Breeding success, diet and brood neglect in the Kittiwake (*Rissa tridactyla*) over an 11-year period. ICES J. Mar. Sci. 54: 615-623.

Harris M.P., Halley D.J. & Swann R.L. 1994. Age of first breeding in common murres. The Auk 111: 207-209.

Harris M.P., Wanless S. & Rothery P. 1983. Assessing changes in the numbers of Common Guillemots *Uria aalge* at breeding colonies. Bird Study 30: 57-66.

Heubeck M. 1998. SOTEAG ornithological monitoring programme 1997 summary report. SOTEAG, Aberdeen.

Heubeck M., Meek E. & Suddaby D. 1992. The occurrence of dead auks Alcidae on beaches in Orkney and Shetland, 1976-1991. Sula 6: 1-18.

Heubeck M., Mellor R.M. & Harvey P.V. 1997. Changes in the breeding distribution and numbers of Kittiwakes *Rissa tridactyla* around Unst, Shetland, and the presumed role of predation by Great Skuas *Stercorarius skua*. Seabird 19: 12-21.

Heubeck M., Mellor R.M., Harvey P.V., Mainwood A.R. & Riddington R. 1999. Estimating the population size and rate of decline of Kittiwakes *Rissa tridactyla* breeding in Shetland, 1981-97. Bird Study 46: 48-61.

Jones P.H. 1978. Surveillance of cliff-nesting seabirds at their breeding sites in Orkney, 1976-77. Nature Conservancy Council Commissioned Research Report No. 212.

Lloyd C., Tasker M.L. & Partridge K. 1991. The status of seabirds in Britain and Ireland. T. & A.D. Poyser, London.

Meek E.R., Sim I.M.W. & Ribbands B. 1994. Breeding skuas in Orkney: the results of the 1992 census. Seabird 16: 34-40.

Paice D. 1993. Monitoring of breeding success of cliff-nesting seabirds in Orkney, 1993. Joint Nature Conservation Committee Report No. 190.

Planterose B. 1979 Report of Orkney summer warden 1979 – Marwick Head. RSPB unpublished report.

Ribbands J.B. 1990. Monitoring breeding success of cliff-nesting seabirds in Orkney in 1989. Nature Conservancy Council Chief Scientist's Directorate Report No. 1017.

RSPB 1978–1998. Orkney beached bird survey reports. Unpublished RSPB series of annual reports.

Sclater P. (ed) 1998. Shetland Bird Report 1997. Shetland Bird Club, Lerwick.

Tasker M.L. 1983 Surveillance of cliff-nesting seabirds in Orkney, 1983. Nature Conservancy Council Chief Scientist Directorate Report No. 490.

Thomas C.J. 1988. Surveillance of cliff-nesting seabirds in Orkney, 1988. Nature Conservancy Council Chief Scientist Directorate Report No.872.

Thompson K.R., Pickerell G & Heubeck M. 1999. Seabird numbers and breeding success in Britain and Ireland, 1998. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No. 23).

Walsh P.M., Halley D.J., Harris M.P., del Nevo A., Sim I.M.W & Tasker M.L. 1995. Seabird monitoring handbook for Britain and Ireland. JNCC, Peterborough.

Wanless S., Reynolds P. & Langslow D.R. 1982a. Surveillance of cliff-nesting seabirds in Orkney, 1980-81. Nature Conservancy Council Commissioned Research Report No. 368.

Wanless S., French D.D., Harris M.P. & Langslow D.R. 1982b. Detection of annual changes in the numbers of cliff-nesting seabirds in Orkney 1976-80. J. Anim. Ecol. 51: 785-795.

Wanless S., Reynolds P. & Langslow D.R. 1983. Surveillance of cliff-nesting birds in Orkney 1982. Nature Conservancy Council Chief Scientist Directorate Report No. 452.

Ward R.M. 1987. Surveillance of cliff-nesting seabirds in Orkney, 1987. Nature Conservancy Council Commissioned Research Report No. 759.

Wilkinson L. 1990. SYSTAT: The system for statistics. SYSTAT Inc., Evanston.

Wooler R.D. & Coulson J.C. 1977. Factors affecting the age of first breeding of the Kittiwake *Rissa tridactyla.* Ibis 119: 339-349.