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Development of MSFD Indicators, Baselines and Target for the Annual breeding Success of Kittiwakes in the UK (2012)

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Summary

1. The Marine Strategy Framework Directive (MSFD) has been developed with the objective of achieving Good Environmental Status (GES) across Europe's marine environment by 2020. Seabirds have long been proposed as valuable indicators of the health of the marine environment.

2. One of the definitions of GES is that "the distribution and abundance of species should be in line with prevailing physiographic, geographic and climatic conditions". However, seabirds are typically long-lived, with expected lifespans of several decades, so changes in abundance often show a marked lag following any change in environmental drivers. Demographic parameters, like breeding success, are often more responsive to environmental changes than changes in population size. Seabird breeding success has been shown to be closely linked to food quality and availability. Consequently, tracking breeding success over a broad spatial scale would provide a valuable tool with which monitor the effect of anthropogenic activities on the wider marine environment.

3. Kittiwakes (*Rissa tridactyla*) are considered to be highly sensitive to changes in food supplies as they show little ability to exploit alternative fish species if their main prey is unavailable; therefore they are an excellent candidate for an indicator species of sandeel availability. Previous work by Frederiksen *et al* (2004, 2007) found kittiwake breeding success in eastern Scotland and eastern England to be significantly negatively correlated with local mean winter Sea Surface Temperature (SST) during February and March of the previous year.

4. Here, we develop this approach to derive an indicator of kittiwake breeding success at colonies around the UK based on data held by the Seabird Monitoring Programme (SMP), separately for the Greater North Sea (GNS) and Celtic Seas (CS) sub-regions of the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic. We then conduct a trial assessment of the proposed target ("Annual breeding success is not significantly different, statistically, from the level expected in the prevailing climatic conditions in five years out of six") for these indicators.

5. Kittiwake breeding success data were available from the Seabird Monitoring Programme (SMP) for the period 1986–2010. Twenty-nine colonies were identified as having sufficient data for the GNS sub-region, and ten for the CS sub-region.

6. Baseline breeding success was calculated using generalised linear mixed-effect models fitted with either a single fixed slope, i.e. we assumed differences in the relationship between breeding success and SST between colonies were primarily due to sampling variation or a colony-specific random slope to take into account colony-specific differences in the relationship between breeding success and SST at each colony.

7. The fixed-slope model and the random-slope model produced different baseline and target breeding success. The fixed-slope model was more conservative than the random-slope model and thus resulted in a greater number of colonies failing to reach the target in a given year and lower proportion of years in which the target breeding success was met in each colony.

8. The two sub-regions did not differ to a great extent in the percentage of years in which the targets were met, but within the GNS there was a much greater likelihood in failure among colonies in Orkney and, especially, Shetland, than elsewhere on the eastern side of Britain.

9. Since 2000 there has been a gradual decline in the proportion of colonies contributing to the SMP database that are achieving the target breeding success, irrespective of which model is used. This decline appears to be similar in the two regions and it suggests that pressures acting in the marine environment continue to be severe.

10. The annual breeding success indicator for the GNS should be equal or greater than 93% in any given year, and the indicator for CS should provisionally be considered as 96% success until more reliable data for the sub-region are collected. The indicator should be presented on an annual basis in the form of a map illustrating success per each colony in each year and in respect to the long–term trend.

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1 Introduction

1.1. The Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC) has been developed with the objective of achieving Good Environmental Status (GES) across Europe's marine environment by 2020. GES is defined by 11 qualitative descriptors listed in the Directive (Com Decision 2010/477/EU). Of particular relevance to this project is the descriptor D1 – Biological Diversity, which stipulates "Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species should be in line with prevailing physiographic, geographic and climatic conditions."

1.2 Kittiwake Breeding Success as an Indicator of Good Environmental Status

Previous work by Frederiksen *et al* (2004, 2007) found kittiwake *Rissa tridactyla* breeding success on the Isle of May, Firth of Forth and at six other colonies in eastern Scotland and eastern England to be significantly negatively correlated with local mean winter Sea Surface Temperature (SST) during February and March of the previous year. This was proposed to be as a result of warmer winters resulting in lower 0 group sandeel *Ammodytes marinus* recruitment, which subsequently leads to a reduced availability of 1 group sandeel in the following year which are a key prey resource for kittiwakes in colonies around the North Sea. Frederiksen *et al* (2004) suggest that kittiwake breeding success following a warm winter is not notably impacted as adults and chicks do not feed on 0 group sandeels until June. However, in the following year, breeding kittiwakes are feeding on a weak year class at the start of the season, which leads to poorer body condition of individuals and hence lower breeding success. Moreover, it was shown that, in years when the sandeel fishery was active, kittiwake breeding success was significantly lower compared to years when the EU sandeel fishing ban was imposed (Frederiksen *et al* 2004, 2007). The authors went on to highlight that climate change models have predicted further increases in North Sea temperatures, and it was proposed that the fishing ban remain in place indefinitely as a precautionary measure.

One of the definitions of GES is that "the distribution and abundance of species should be in line with prevailing physiographic, geographic and climatic conditions". Seabirds are typically long-lived species (Gaston 2004), so changes in population numbers often show a marked lag following any change in environmental drivers. Consequently, demographic parameters, like breeding success, are often more responsive to environmental changes than changes in population size (Harris & Wanless 1990; Furness & Camphuysen 1997; Rindorf *et al* 2000; Wanless *et al* 2007). Kittiwakes are considered to be highly sensitive species to changes in food supplies as they show little ability to exploit alternative fish species if their main prey is unavailable (Furness & Tasker 2000). They are therefore an excellent candidate for an indicator species of sandeel availability[1]. In accurately assessing the impact of pressures stemming from anthropogenic activities, such as commercial fishing, it is necessary to account for variation due to more natural factors, such as climate variability. The strong relationship between kittiwake productivity and SST, at least in colonies surrounding the North Sea (Frederiksen *et al* 2004), make it possible, in any statistical models, to control for the impact of climate on changes in breeding success and to focus on how other anthropogenic activities affect the availability of, and access to, food supplies.

[1] Indicators proposed by Defra's *MSFD Consultation Paper: UK Initial Assessment and proposals for Good Environmental Status;* and proposed as part of a common set of indicators to be adopted by Member States in the North-east Atlantic Region (see OSPAR Commission 2012).

1.3 Objectives

This project will construct an indicator of kittiwake breeding success that has a baseline and a target that will enable assessment of whether or not Good Environmental Status has been achieved under the Marine Strategy Framework Directive. The aim of the project will be to develop a clear process that constructs the indicator from monitoring data and assesses the indicator against a target, which reflects GES.

The work had the following objectives:

- To derive an indicator of kittiwake breeding success at colonies around the UK based on data held by the Seabird Monitoring Programme (SMP).

- To set a baseline and target for each selected colony.

- To conduct a trial assessment of the proposed target ("Annual breeding success is not significantly different, statistically, from the level expected in the prevailing climatic conditions [defined by local SST in winter 2 years previously] in five years out of six") for these indicators.

- To carry out separate assessments in order to determine whether GES has been achieved for the Greater North Sea and Celtic Seas sub-regions[2] of the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic.

[2] United Kingdom waters and fall into Greater North Sea and Celtic Sea sub-regions of the North East Atlantic Marine Region set out in the MSFD. The boundaries of these sub-regions closely equate to the OSPAR Greater North Sea and Celtic Sea regions, so seabird breeding colonies were assigned to one sub-region or another according to the OSPAR regional boundaries for this project.

2. Methodology

2.1 Sea Surface Temperature Data

Following Frederiksen *et al* (2004), SST data for the Greater North Sea and Celtic Seas sub-regions were obtained for the February and March of the year preceding each breeding season. They propose that warmer winters result in lower recruitment of sandeel of the current year cohort (Group 0), subsequently leading to a reduced availability sandeel in the following year (Group 1). Kittiwake breeding success is not affected immediately following a warm winter because neither adults nor chicks feed on Group 0 sandeel until June (Frederiksen *et al* 2004). However, birds are affected in the following year when they feed on a weak year class at the start of the breeding season, which leads to poorer breeding condition and lower breeding success. Data were obtained from the Hadley Centre Sea Ice and Sea Surface Temperature (HadISST) dataset (Rayner *et al* 2003) and processed using the ncdf package within R (Pierce 2011).

Initially, we constructed an SST index based on the whole area in each of the two sub-regions. To check the validity of this, we constructed general linear models (i.e. using a normal error distribution, since this proved a better fit to the data than a Poisson model) to relate breeding success (BS) to SST and looked at the distribution of slopes (Figure. 1). There did not appear to be marked differences between the strength of the relationship in the GNS and CS sub-regions, however, there did appear to be substantial heterogeneity within the GNS region, with colonies north of about 56°N showing a marked negative relationship, the relationship was much shallower for more southerly colonies. Therefore, we divided the GNS into a northern and southern region (at 56°N) and modelled breeding success in relation to mean SST calculated for the appropriate region; there were an insufficient number of colonies to justify subdividing the CS sub-region. This division also reflected differences in breeding success found by Cook and Robinson (2010), who identified three broadly geographical clusters of breeding success in the UK (Shetland, eastern Britain and the CS sub-region).

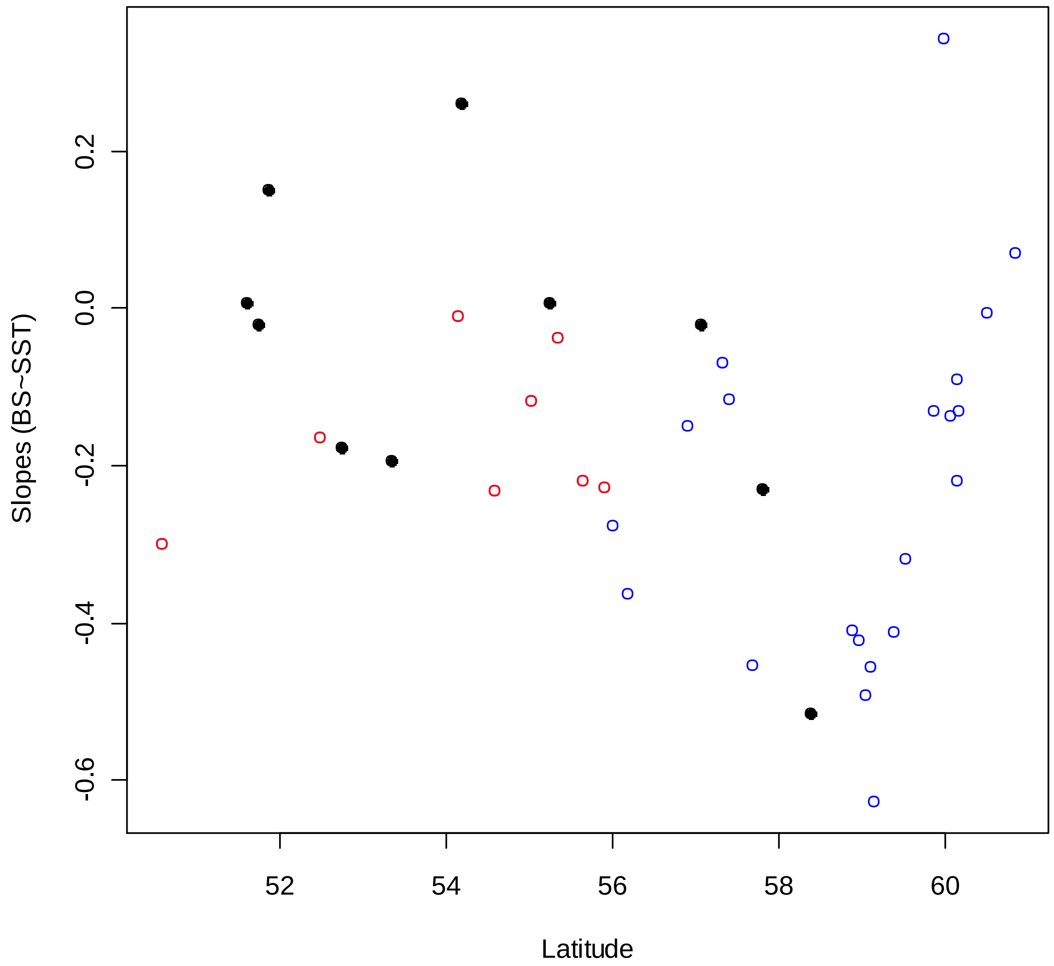

Figure 1. Variation of the relationship and baselines for GES between breeding success and SST with latitude for colonies in the Greater North Sea (northern Isles (blue dots) and South North Sea (red dots) and Celtic Seas (black dots) subregions.

2.2 Colony Selection

Kittiwake breeding success data were available from the Seabird Monitoring Programme (SMP) for the period 1986–2010. However, there was variation in the colonies that were surveyed on a year to year basis. It is important to ensure that the models underlying these indicators are statistically robust, and that the data that feed into them are sufficient to detect a significant relationship with SST, where it exists.

With this in mind, the relationship between SST and kittiwake breeding success at every colony surveyed between 1986 and 2010 was analysed using a linear regression. The mean effect size for SST was calculated for all colonies at which a significant, negative effect was detected. This mean effect size was used within a power analysis framework in the R statistical package pwr (Champely 2012) to calculate the minimum number of years data required to detect a relationship between kittiwake breeding success and sea surface temperature that was significant at the level of 0.05 and had a power of 0.8. All colonies within the Greater North Sea and Celtic Seas sub-regions which had sufficient data to detect a significant relationship were identified (Figure. 2).

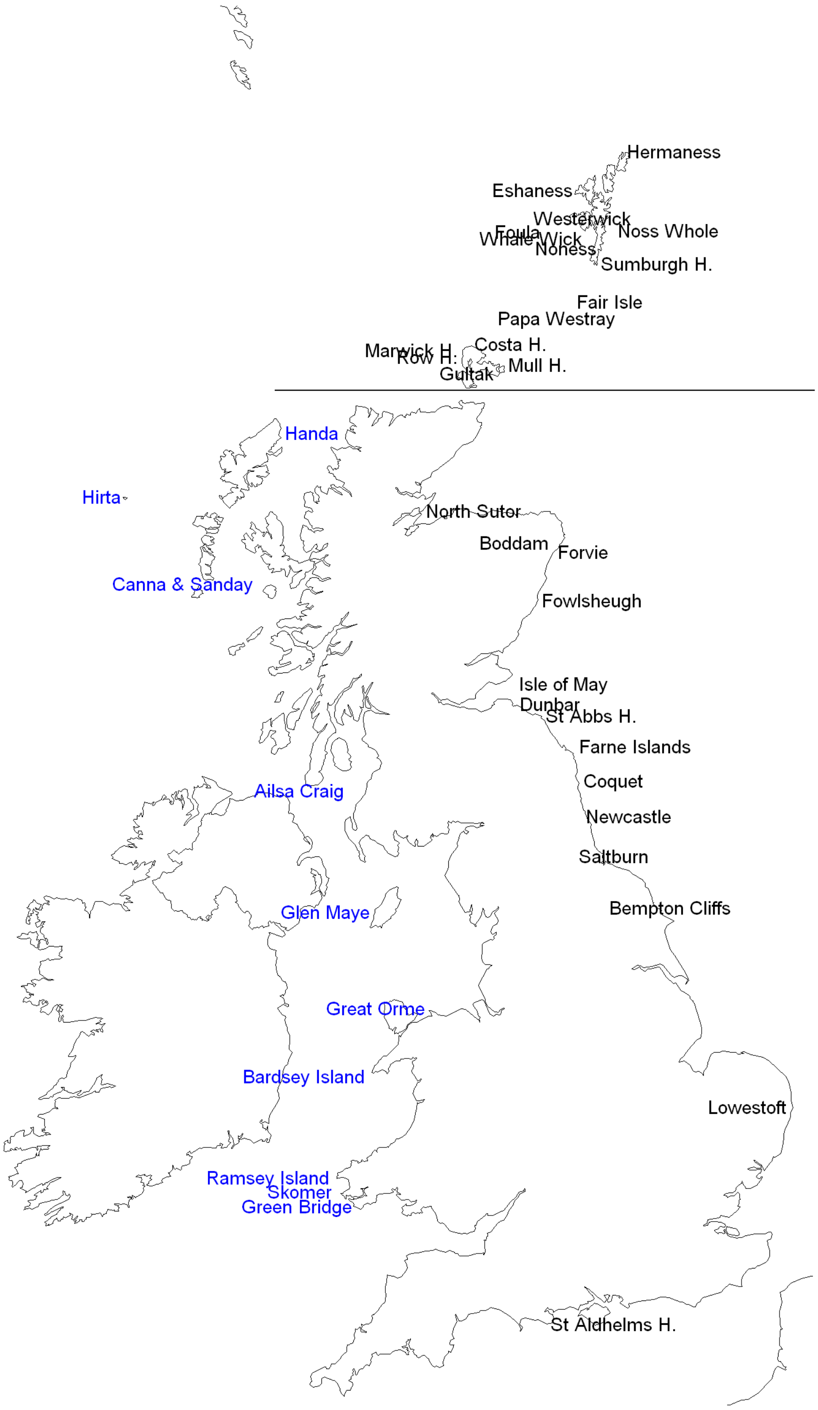

Figure 2. Kittiwake colonies used in this study: Great North Sea in black (29 colonies), Celtic Sea in blue (10 colonies). The black line demarcates the division between the north and south subdivisions of the GNS.

2.3 Deriving Targets and Baselines for Selected Colonies

In this study, a baseline level of breeding success for each colony in each of the two sub-regions was calculated alongside a target level that would need to be reached in order to achieve Good Environmental Status.

As expected there was generally a negative relationship between breeding success (BS) and SST (with lower BS in years when water temperatures were higher the previous winter). There was some variation in this relationship between colonies, with some showing a greater reduction in breeding success in response to SST than others. The relationship was statistically significant (at 95% confidence level) for five colonies, and almost significant (at 90% confidence level) for a further three colonies in the GNS sub-region. The relationship was not significant for any of the colonies in the CS sub-region. The impact of SST was greater in the GNS region with all slopes being negative; in the CS the slopes were generally much shallower (Figure. 3). The variation within each region could reflect differing strengths of the biological mechanism, perhaps as a result of individuals at different colonies relying on Group 1 sandeels to differing extents, thus weakening or strengthening the apparent relationship with SST. Alternatively, the differences could simply reflect sampling variability since colonies were covered in differing years and sampling intensity differed between colonies. Therefore, two models were used to address those two scenarios:

a) the baseline BS was calculated using a mixed-effect GLM with annual breeding success as the response variable, expressed as the mean number of young fledged per pair[3], SST as a fixed effect and colony as random effect (i.e. colonies were allowed to differ in their overall level of success). The relationship between BS and SST was fitted as a single fixed slope, i.e. assuming differences in the relationship between the two variables were primarily due to sampling variability and that the same relationship underlies variation in BS at all colonies;

b) the second model was similar to the first, but specified a random slope for the relationship between breeding success and SST as well as the colony random effect to take into account differences in the relationship between breeding success and SST at each colony. Thus, the slope for each colony could be more or less negative than the average and colonies closer together may have more similar slopes than those separated by greater distances.

[3] Breeding success was calculated as the total no number of young fledged divided by the total number of breeding pairs.

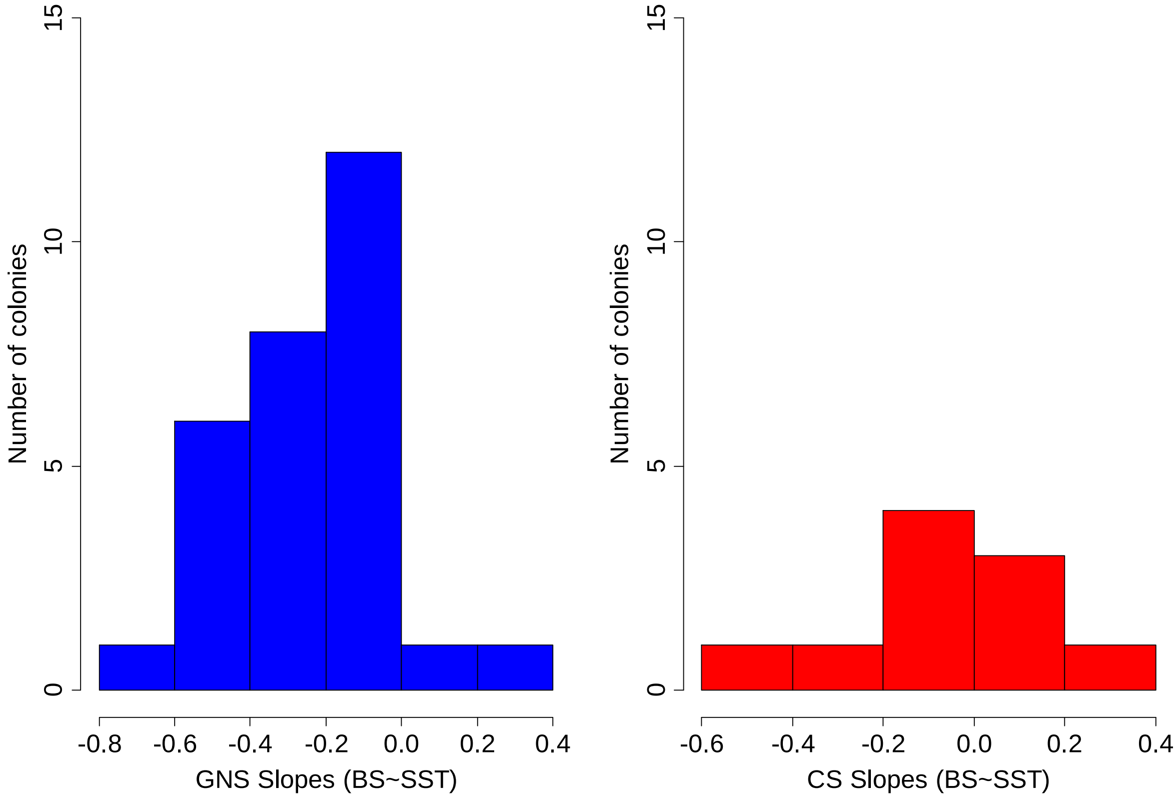

Figure 3. Frequency distribution of slopes of the relationship between breeding success and sea surface temperature for colonies in the Great North Sea sub-region (blue) and Celtic Sea sub-region (red).

Given the apparent variation in the relationship between SST and breeding success at each colony, scenario (b) is, perhaps, a more intuitive descriptor of the data. However, measurement of breeding success is subject to sampling variation thus there will be some variability in the estimated slope for each colony. Therefore, it is plausible that the underlying relationship between SST and breeding success is, in fact, constant across colonies (a unit increase in SST results in an equal change in breeding success) and that the apparent variability is due to chance. As it is difficult to directly compare the goodness of fit of the two models, we present both.

Because the number of young hatching per nest (an integer number, either 0, 1 or 2) did not follow a standard distribution (for example, a Poisson distribution would include a substantial frequency >2, which is clearly impossible for a bird that lays only 2 eggs), we modelled breeding success as the number of young fledged per egg, which will have a binomial distribution as each egg will either produce a fledged chick, or not. As colonies differed greatly in size, weighting was introduced in both models to account for different number of nests found in each colony. Models were fitted for each sub-region (GNS and CS) separately using *lmer* from the lme 4 package in R 2.12.0 (Bates *et al* 2011).

Baseline breeding success was calculated using each of the two models, and the 95% upper and lower intervals around each baseline were used to define the upper and lower thresholds of the target breeding success (Figure. 4). Of these, it is the lower confidence interval that is of most interest, since colonies failing to achieve this level of breeding success are doing worse than would be expected by chance variation alone.

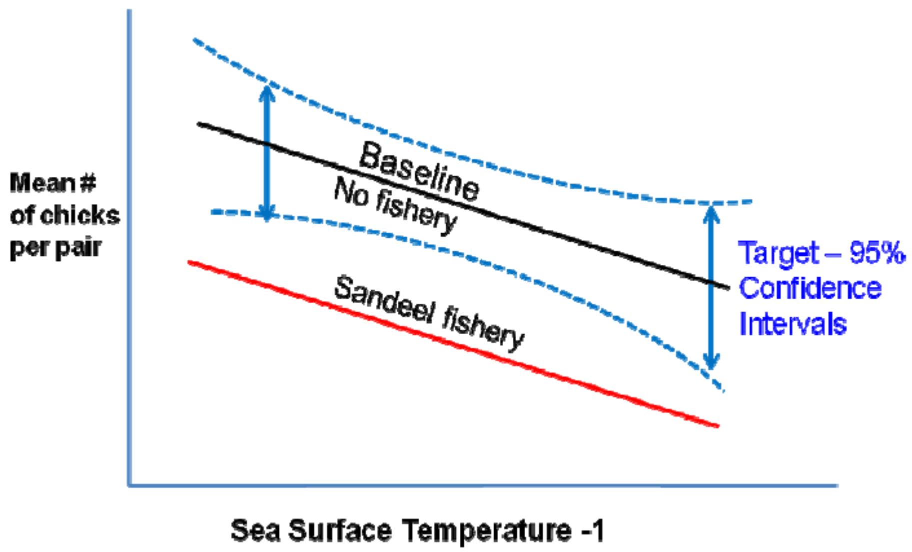

Figure 4. Schematic relationship between kittiwake breeding success and winter Sea Surface Temperature (SST) of the previous year (from Frederiksen *et al* 2004, 2007).

2.4 Conducting Trial Assessments of the Target

After obtaining two sets of target breeding success using the fixed-slope and the random-slope models, the following step involved calculating whether the observed breeding success in colonies in the two sub-regions (GNS and CS) met those targets in at least five years out of six. As a trial target we used: “Annual breeding success is not significantly different, statistically, from the level expected in the prevailing climatic conditions (defined by local SST in winter 2 years previously) in five years out of six.”

The observed breeding success of each colony in each year was compared with the lower confidence interval around the target values (i.e breeding success, accounting for climate variability) identified by the fixed-slope model and random-slope model. If the observed breeding success fell below the lower confidence interval of the target accounting for SST, the colony was identified as not having achieved the target breeding success. The two sub-regions (GNS and CS) were considered separately. The function *running* was then used to calculate how many years within a six-year period the colony had failed to meet the target breeding success from 1991 onwards (data on breeding success were available since 1986, therefore 1991 was the first year with a six-year period before it). Finally, the percentage of times that the colony had achieved the target value in at least five years out of six was also calculated.

2.5 Investigating How to Aggregate Colony-Specific Assessments at the Sub-Regional Scale

Knowing the percentage of colonies that meet the target breeding success each year allows one to evaluate if there is a pattern between years, and predict how many colonies would be expected to miss targets by chance and the number of colonies that can miss the target before there is a repercussion at a population level. Colonies in close proximity, however, are likely to experience similar environmental factors, including food supplies, such spatial clustering can bias results and lead to erroneous conclusions if pressures are particularly intense in only parts of the larger region over which the indicator is calculated. The potential for geographic clustering was identified visually using Figure 1 and Figure 5. The former figure, in particular, helped identify two separate regional clusters between the northern colonies and the southern ones in their response to SST (see above). Only GNS colonies could be split between north (at or above latitude 56N) and south (below latitude 56N), whilst CS colonies were too few to be split for statistical analyses.

The number of colonies achieving the target for kittiwake breeding success each year was calculated for the two models: one mixed effect model specified fixed slope for the relationship between breeding success and sea surface temperature for each colony, the second model, similar to the first one, specified random slopes for the same relationship (see above). The percentage of colonies expected to fail by chance was calculated using a generalised linear model using failure/success to meet the target breeding success specified by each model for each of the two sub-regions as the response variable, and year and site as covariates, specifying the distribution family as binomial. Those values represented the probability of success, and 1 minus those values provided the probability of failure by chance. The mean and relative confidence intervals of failure probability across all years for each sub-region per each model were also calculated to use as reference for expected failure rate occurring by chance in each sub-region.

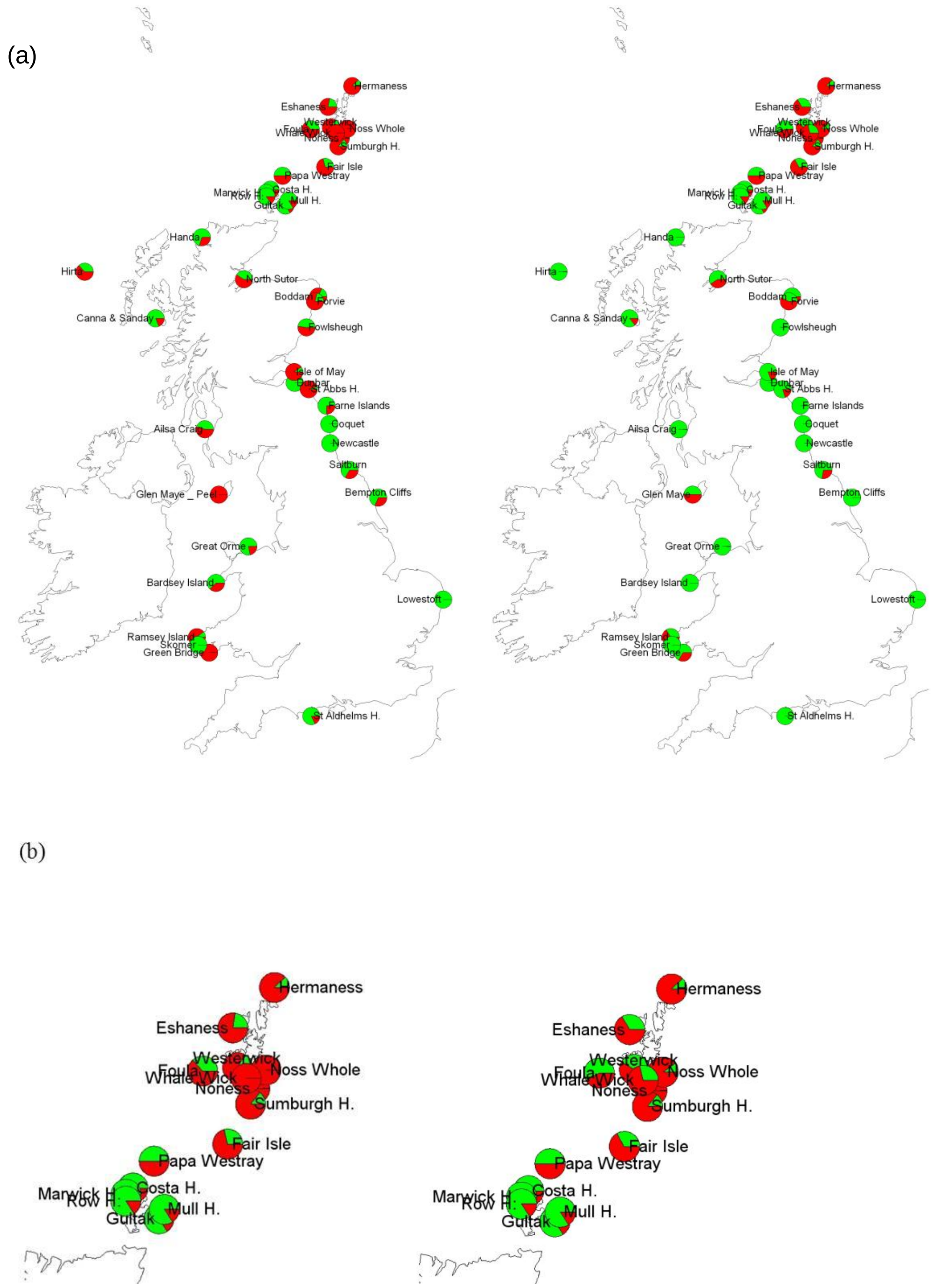

Figure 5. (a) Proportion of years in which the target breeding success is met in each colony, and the Northern Isles of the Great North Sea sub-region in particular (b) if model with fixed slope (left) or random slopes (right) are considered.

3. Results

3.1 Colony Selection

Power analyses indicated that for colonies situated in the Great North Sea sub-region a minimum of 13 annual estimates of breeding success out of a possible 25 years (1986-2010) were needed to achieve robust statistical results. Data from 29 colonies from GNS sub-region met this criterion and were consequently included in the analyses. In order to produce the same level of power as in the GNS data, a minimum of 23 annual estimates of breeding success would be required from colonies in the Celtic Sea, where coverage of colonies is less consistent between years. This criterion would have been met by only five colonies, so the threshold was lowered to 13 years to reflect the same used for GNS colonies, as the two sub-regions showed similar relationship between breeding success and SST (Figure. 3), resulting in 10 colonies from the CS sub-region being included in the analyses.

3.2 Deriving Targets and Baselines for Selected Colonies

The fixed-slope model and the random-slope model (Table 1) produced different baseline and target breeding success (Tables A1 & A2). The model with fixed slope was, perhaps unsurprisingly, more conservative, with higher target breeding success and narrower confidence intervals since all colonies were treated equally. Also, because colonies were treated equally, the high frequency of failure in some colonies resulted in more negative slopes. The second model, with random slopes, produced lower target breeding success than the fixed-slope model, and wider confidence intervals. For the GNS sub-region the relationship between breeding success and SST was still estimated as significantly negative, however, for the CS sub-region there was essentially no relationship detected between breeding success and SST (Table 1). The random slope specified in the second model removed variability related to each colony, with a better estimate of the overall standard error as a result. The random-slope model will also have better accounted for spatial autocorrelation as each colony was taken into account separately and colonies close to each other will have more similar slopes than those separated by a greater distance.

Table 1. Parameter estimates of the fixed-slope model with GNS sub-regions (a) and CS sub-regions (b) and parameter estimates of the random-slope model with GNS sub-regions (c) and CS sub-regions (d).

Parameter	Type of effect	Estimate	Std Err	z-value	p-value
GNS: Fixed-slope model					
SST	Fixed	-0.337	0.001	-1116.8	<0.0001
Colony	Random	0.12	0.35	NA	NA
CS: Fixed-slope model					
SST	Fixed	-0.183	0.018	-10.47	<0.0001
Colony	Random	0.14	0.38	NA	NA
GNS: Random-slope model					
SST	Fixed	-0.18	0.05	-3.40	<0.001
Colony	Random	4.76	2.18	NA	NA
SST/Colony	Random	0.08	0.28	NA	NA
CS: Random-slope model					
SST	Fixed	0.07	0.24	0.30	0.77
Colony	Random	45.5	6.7	NA	NA
SST/Colony	Random	0.55	0.74	NA	NA

3.3 Conducting Trial Assessments of the Target

The fixed-slope and random-slope models produced different results. The fixed-slope model was more conservative than the random-slope model and thus resulted in a greater number of colonies failing to reach the target in a given year (i.e. the breeding success was lower than the lower confidence interval around the target breeding success) (Figure 6 and Table 2) and lower proportion of years in which the target breeding success was met in each colony (Figure 5). This was due mainly to two factors: the target values for the fixed-slope model were higher and the confidence intervals around these values were smaller, so that each colony was more likely to miss the target breeding success, per any given year, specified by the fixed-slope model than by the random-slope model.

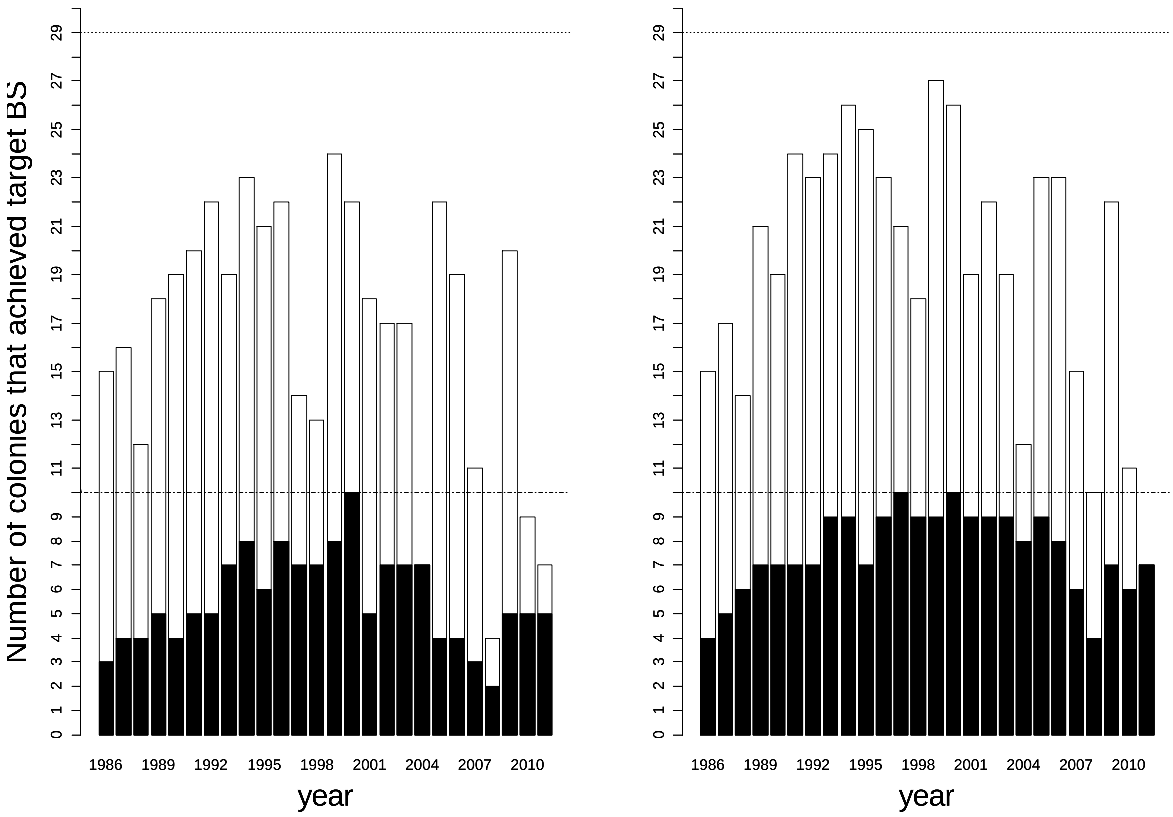

Figure 6. Number of colonies that achieved target breeding success (BS) across years according to the fixed-slope model (left) and the random-slope model (right). Colonies in the Great North Sea (GNS) are in white, those in the Celtic Sea (CS) in black. The upper line identifies the total number of colonies in the GNS sub-region sample (n=29), and the lower line the total number of colonies in the CS sub-region sample (n=10).

Table 2. Number of colonies (and percentage for that year) in the two sub-regions (Great North Sea, GNS and Celtic Seas, CS) achieving target breeding success identified by the fixed-slope model and the random-slope model across years. The total number of colonies considered in this study was 29 for GNS sub-region and 10 for CS.

	Greater North Sea		Celtic Seas	
Year	Fixed Slope	Random Slope	Fixed Slope	Random Slope
1986	15 (51.7%)	15 (51.7%)	3 (30%)	4 (40%)
1987	16 (55.2%)	17 (58.6%)	4 (40%)	5 (50%)
1988	12 (41.4%)	14 (48.3%)	4 (40%)	6 (60%)
1989	18 (62.1%)	21 (72.4%)	5 (50%)	7 (70%)
1990	19 (65.5%)	19 (65.5%)	4 (40%)	7 (70%)
1991	20 (69.0%)	24 (82.8%)	5 (50%)	7 (70%)
1992	22 (75.9%)	23 (79.3%)	5 (50%)	7 (70%)
1993	19 (65.5%)	24 (82.8%)	7 (70%)	9 (90%)
1994	23 (79.3%)	26 (89.7%)	8 (80%)	9 (90%)
1995	21 (72.4%)	25 (86.2%)	6 (60%)	7 (70%)
1996	22 (75.9%)	23 (79.3%)	8 (80%)	9 (90%)
1997	14 (48.3%)	21 (72.4%)	7 (70%)	10 (100%)
1998	13 (44.8%)	18 (62.1%)	7 (70%)	9 (90%)
1999	24 (82.8%)	27 (93.1%)	8 (80%)	9 (90%)
2000	22 (75.9%)	26 (89.7%)	10 (100%)	10 (100%)
2001	18 (62.1%)	19 (65.5%)	5 (50%)	9 (90%)
2002	17 (58.6%)	22 (75.9%)	7 (70%)	9 (90%)
2003	17 (58.6%)	19 (65.5%)	7 (70%)	9 (90%)
2004	7 (24.1%)	12 (41.4%)	7 (70%)	8 (80%)
2005	22 (75.9%)	23 (79.3%)	4 (40%)	9 (90%)
2006	19 (65.5%)	23 (79.3%)	4 (40%)	8 (80%)
2007	11 (37.9%)	15 (51.7%)	3 (30%)	6 (60%)
2008	4 (13.8%)	10 (34.5%)	2 (20%)	4 (40%)
2009	20 (69.0%)	22 (75.9%)	5 (50%)	7 (70%)
2010	9 (31.0%)	11 (37.9%)	5 (50%)	6 (60%)

The two sub-regions did not differ to a great extent in the percentage of years in which the targets were met (Table 3). In both regions, around 55% of the colonies met the target on average when considering the fixed-slope model, and around 75% when considering the random slopes model (Fig. 7). There was, however, some annual variation in this with the figure varying by 10-15% in a given year. There also appeared to be a long-term trend in this (Fig. 7), with the proportion of colonies meeting the target being highest in the late 1990's and early 2000's and having declined since.

Table 3. Percentage of years in which each colony of the two sub-regions (Great North Sea and Celtic Seas) met the target breeding success in at least five years out of six for the two models.

Colonies	Fixed-slope model	Random-slope model
Greater North Sea		
Bempton Cliffs RSPB	68.4	100
Boddam to Collieston	18.8	62.5
Coquet Island	100	100
Costa Head	69.2	69.2
Dunbar Coast & Harbour	100	100
Eshaness	22.2	33.3
Fair Isle	28.6	33.3
Farne Islands	75	100
Foula	36.8	57.9
Fowlsheugh RSPB	47.4	100
Gultak	84.2	84.2
Hermaness	12.5	12.5
Isle of May	9.5	81
Lowestoft	100	100
Marwick Head	80	80
Mull Head	84.2	84.2
Newcastle to Seaton Sluice	100	100
Noness	0	0
North Sutor Of Cromarty Castlecraig	41.2	58.8
Noss Whole Island	0	10
Papa Westray (North Hill RSPB)	50	50
Row Head	84.2	84.2
Saltburn Cliffs (Huntcliff)	66.7	72.2
Sands Of Forvie	21.4	42.9
St Abbs Head NNR	5	80
St Aldhelms Hd to Durlston Hd	81.8	100
Sumburgh Head	14.3	14.3
Westerwick	16.7	41.7
Whale Wick to Sandwick	0	28.6
Celtic Seas		
Ailsa Craig	45	100
Canna & Sanday	81	85.7
Handa	70	100
Hirta	36.8	100
Bardsey Island	62.5	100
Glen Maye to Peel	0	50
Great Orme	78.6	100
Green Bridge of Wales to Flimston Bay	0	66.7
Ramsey Island	11.1	33.3
Skomer	100	100

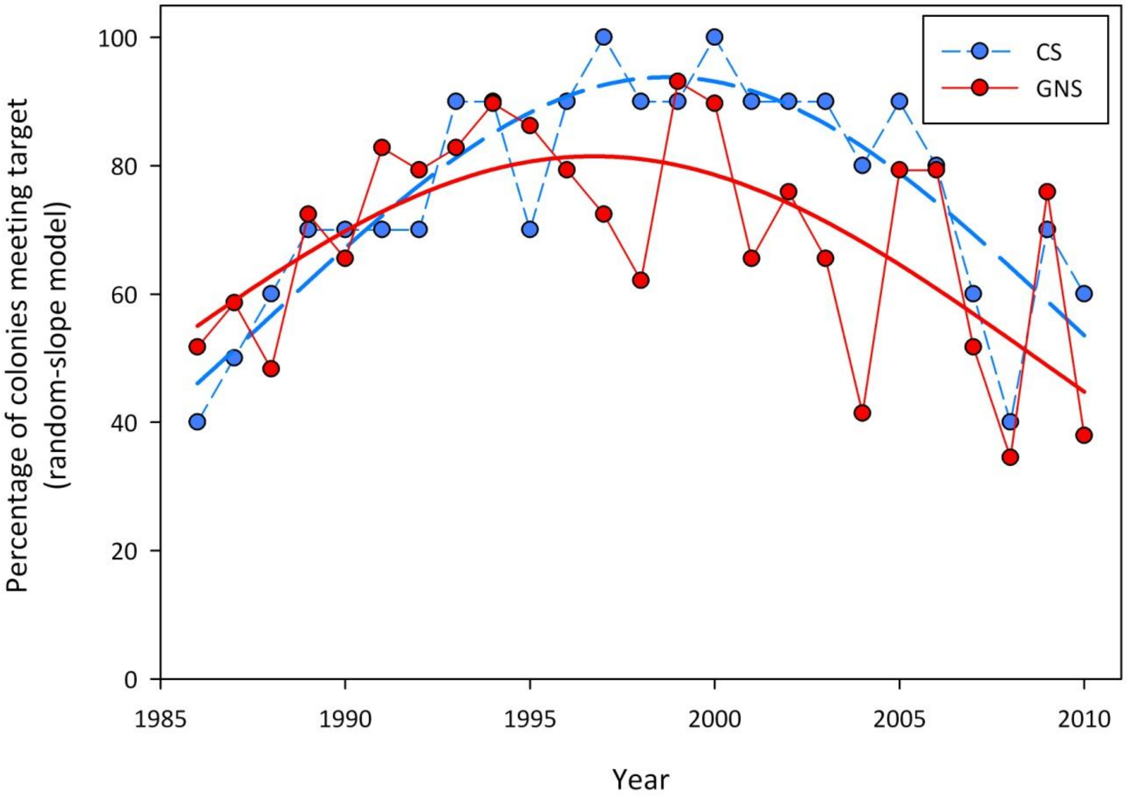

Figure 7. Proportion of colonies meeting the target in each year for the random-slopes model in the Greater North Sea (GNS) and Celtic Seas (CS) regions. The fixed-slope model showed a similar pattern.

3.4 Investigating How to Aggregate Colony-Specific Assessments at the Sub-Regional Scale

The model with fixed slopes was more conservative, producing a higher target breeding success and narrower confidence intervals than the model with random slopes. Figure 6 shows the number of colonies for each sub-region (GNS and CS) which have met the target breeding success indicated by each of the two models. In none of the years did all colonies in the GNS sub-region meet the target values specified neither by the fixed-slope model nor by the random-slope model. In the CS sub-region, all colonies met the target breeding success suggested by the fixed-slope model only once, in 2000, but twice (1997 and 2000) when the targets from the random-slope model were considered. There was a geographic clustering identified within the Northern Isles in the Great North Sea sub-region (Figure 5), with colonies in Shetland particularly prone to failure (Figure 5b). No clustering was found within the Celtic Sea sub-region.

The mean probabilities of failure and confidence intervals for each sub-region under each model are summarised in Table 4. The fixed-slope model provided more conservative results, and under this model about 16% of colonies in the GNS and 4% of colonies in the CS were expected to fail by chance. The relatively poor quality of data available for CS colonies means that the figure, and related confidence intervals, should be regarded with caution. Under the random-slope model 4% of colonies in the GNS sub-region were predicted to fail by chance, but no colonies in the CS sub-region, though this may reflect the fact that fewer colonies were monitored.

Table 4. Probability (95% confidence level) of failure by chance in the two sub-regions (Great North Sea and Celtic Sea) using failure to achieve target breeding success indicated by the fixed-slope model and the random-slope model. Under the fixed-slope model we would expect that between 8% and 24% of colonies in the Great North Sea would not reach the target breeding success, whilst under the random-slope model we would expect between 1% and 7% of colonies to fail to reach the same target. In the Celtic Sea sub-region, we would expect between 30% and 50% of colonies to fail to reach the target breeding success under the fixed-slope model, but none under the random-slope model.

	Greater North Sea			Celtic Sea		
	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI
Fixed-slope	0.16	0.08	0.24	0.40	0.30	0.50
Random-slope	0.04	0.01	0.07	0	0	0

In considering the proportion of colonies failing each year, failure rates registered around the mean should be acceptable and a frequency of failure lower than the lower confidence interval would be desirable. If the frequency of failure increases above the upper confidence intervals expected under a simple model of chance, this should be regarded as critical. Thus, under the fixed-slope model, between 76% and 82% of colonies in the GNS sub-region, and between 50% and 70% in the CS sub-region, should reach the breeding success targets needed to achieve GES. Under the random-slope model, between 93% and 99% of colonies in the GNS sub-region should hit the breeding success target needed to achieve GES. The random-slope model predicted 100% success rate for the CS sub-regions, hence the predicted failure rate was 0%. Under this model it is not possible to predict percentage of failure that can be regarded as critical.

4 Discussion

Kittiwake colonies considered in this study were divided between Great North Sea (GNS) and Celtic Sea (CS) sub-regions. Monitoring effort is generally highest in the Greater North Sea sub-region than in the Celtic Sea, and this difference in data quality was reflected in the number of years of data that needed to be available for each colony: 13 years for GNS and 23 years for CS. This threshold identified 29 colonies for GNS and five for CS. The number of colonies initially selected for CS sub-regions was insufficient for analyses, therefore the threshold was lowered to 13 years of data run as per GNS sub-regions, with a total of 10 colonies identified (Figure 2). The sparseness of the data available for the CS region may have affected our assessment against the target measure, primarily because the target measure (namely, a certain level of breeding success relative to the prevailing climatic conditions) could not be quantified as accurately. Consequently, we advocate improved sampling of breeding success in this region, which should be particularly aimed at more consistent monitoring of existing colonies between years (for example those colonies such as Calf of Man, Mull of Galloway, Lundy, Puffin Island and Berry Head which are already close to the minimum number of years of monitoring needed to produce reliable results). This could be achieved, for example, by trying to involve more volunteer recorders and/or involve site wardens to organise volunteers or carry out the monitoring in person.

The relationship between breeding success and SST was similar, but not identical, across colonies. This may reflect error inherent in the sampling, or a true difference in the resource use or behaviour of individuals at different colonies. The latter could be likely mediated by differences in sandeel stock around each colony. Following warm winters, recruitment of sandeel of the current year cohort (Group 0) is low, subsequently leading to a reduced availability in the following year (Frederiksen *et al* 2004, 2007). Frederiksen *et al* (2004) had identified fisheries as the main explanatory variable for the variation of breeding success across years (accounting for 40-70%, depending on which years fisheries were defined as present) with SST explaining a further 40% (Table 1 in Frederiksen *et al* 2004). In the single colony models of this study SST explained only between <1% and 28% of breeding success in the GNS sub-regions (Eshaness and North Sutor, respectively), and between <1% and 19% for the CS sub-regions (Ailsa Craig and Hirta, respectively), perhaps reflecting that colonies do not depend entirely on sandeels. The slopes recorded here (Table 3) were also shallower than the slope found by Frederiksen *et al* (of -0.42 from Figure 3), indicating a less strong relationship. Values for Sea Surface Temperature used in this study were not the same as those used by Frederiksen and colleagues: in this case we used a different dataset on a larger geographic scale because sandeel banks are inter-connected (Figure 12 in Christensen *et al* 2008) and Dogger Bank, in particular, gains recruits from other areas. Furthermore, Frederiksen and colleagues knew where birds from the Isle of May fed and they could use local SST temperatures. In this study, however, it was not known where birds from each colony foraged; therefore a larger geographic scale for SST was used to preserve consistency between colonies. This may reflect the broader spread of colonies and a longer run of years used in this study, it does, however, suggest that the relationship between breeding success and sea surface temperature may not be as simple as it seems at first sight.

Target breeding successes generated by the two models were different: the fixed-slope model produced higher target values than the random-slope model and narrower confidence intervals, with more colonies, as a consequence, falling below the lower confidence interval of the fixed-slope model than for the random-slope model. The number of colonies meeting the target each year also varied according to the two models. Under the fixed-slope model, in none of the years did all colonies in the GNS sub-region meet the target specified by the fixed-slope model or the random-slope model. All colonies in the CS sub-region met the target breeding success specified by the fixed-slope model in one year, but they all achieved the target in two years. Under the fixed-slope model, some colonies in the CS sub-region, like ‘Glenn Maye to Peel’, seemed to suffer a particularly high likelihood of being classified as failing.

Within the GNS there was a much greater likelihood in failure among colonies in Orkney and, especially, Shetland, than elsewhere on the eastern coast of Britain. The likelihood of colonies failing to meet the target in the CS region was intermediate between the northern and southern east coast colonies. This geographical structuring is in line with that suggested by Cook and Robinson (2010), who identified three broadly similar geographical clusters of breeding success. They found that, in all three regions breeding success appeared to be declining, though the declines in Shetland (-0.022 ± 0.012) were only marginally steeper than those in colonies around the Celtic Sea (0.021 ± 0.010) and in eastern Britain (-0.019 ± 0.011), which accords with results found here. In considering an indicator of breeding success, then, it would be advisable to have a separate indicator for the Northern Isles to fully characterise the geographical variation in breeding success.

The number of colonies expected to fail to meet the target breeding success differed between the fixed-slope model and the random-slope model. Under the fixed-slope model, 16% of colonies in the Great North Sea area are expected, on average, to fail to meet the target breeding success, and this value should be considered normal, while the critical threshold failure rate identified by the model is around 24% of colonies failing for the same sub-region. For the Celtic Sea sub-region colonies, the expected failure rate due to chance is about 4%, with a threshold for repercussion on the population at around 5%. The random-slope model expected 4% failure due to chance in the GNS sub-region but no failure in the CS sub-region. The model may therefore be unsuitable to reliably predict a failure rate due to chance in the CS sub-region.

The recommended model to attain Good Environmental Status is the random-slope one, which provided more conservative results but fitted the data better than the fixed-slope model (a visual output for this indicator is shown in Figure 8). Targets to obtain GES should aim, therefore, to a maximum of 7% failure by chance for the GNS colonies in any given year (93% success) (Table 4), which equates to about 2 colonies in 29 failing by chance. Ideally, the same model would be used to identify targets for colonies in the CS; however, the monitoring of breeding success in that sub-region was too variable to obtain data accurate enough for a reliable result (100% success suggested by the random-slope model for CS is not realistic). It is, therefore, not possible at this stage to recommend a target breeding success, based on the random-slope model, to attain GES in the Celtic Sea sub-region, until more consistent monitoring is carried out and data can provide a reliable result. An alternative in the meantime is to base GES on results from the fixed-slope model, which suggested 4% failure due to chance, or 1 colony failing every two years. This result is not as reliable as one that may be obtained with the random-slope model based on data from more consistent monitoring.

We recommend that the target for the indicator on the annual breeding success of kittiwakes in the Greater North Sea be amended to 7% failure in any given year, and that the indicator be presented on an annual basis in the mode of Figure 8. Further research is needed to determine the principal drivers of the change in kittiwake breeding success.

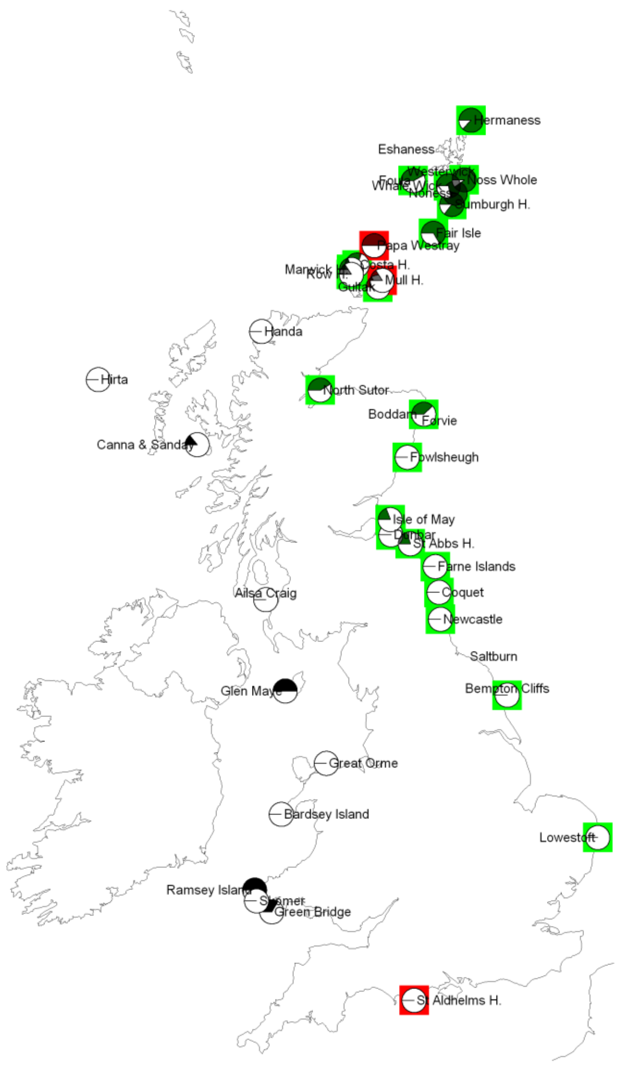

Figure 8. Good Environmental Status (GES) indicator in 2009. The map shows that GES was not met in 2009 as three colonies (red background) in the Great North Sea sub-region did not meet the predicted breeding success (green background) in 2009; the threshold, based on results from the random-slope model, was two colonies failing by chance. The pie charts indicate the proportion of years that the predicted breeding success was achieved (white) or not achieved (black) per each colony from 1991 to 2010. Colonies in the Celtic Sea could not be considered because the model did not reliably fit the data from that sub-region.

Annual breeding success of black-legged kittiwakes (*Rissa tridactyla*) is not significantly different, statistically, from the level expected in the prevailing climatic conditions (defined by local SST in winter 2 years previous winter) in five years out of six, at ≥93% of UK colonies in the Greater North Sea.

The indicators developed here are among the first to account for natural variability in population processes, and so better indicate anthropogenic pressures on bird populations, in this case reduced availability of sandeel prey. It is notable in this regard that colonies in the Northern Isles, in particular in Shetland, failed to meet the target more frequently than colonies elsewhere, given the reliance of Shetland kittiwakes on sandeels as prey (Hamer *et al* 1993; Frederiksen *et al* 2005). However, it may be helpful to relate the incidence of failure to meet the target to statistics on fisheries stock to verify that such a relationship does indeed exist. Since 2000 there has been a gradual decline in the proportion of colonies contributing to the SMP database that are achieving the target breeding success, irrespective of which model is used (Table 2). This decline appears to be similar in the two regions (Figure 7) and it suggests that pressures acting in the marine environment may continue to be severe.

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6 Appendix

Table A 1. Predicted values, lower confidence intervals and whether the recorded success per egg (breeding success/2) has achieved the target value (1=achieved; 0=not achieved) specified by the fixed-slope model and the random-slope model for each colony of the GNS sub-region for each year.

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Bempton Cliffs RSPB	1988	0.354	0.326	0.301	0.139	0.265714	0	1
Bempton Cliffs RSPB	1989	0.273	0.249	0.261	0.110	0.605263	1	1
Bempton Cliffs RSPB	1990	0.244	0.222	0.246	0.100	0.760204	1	1
Bempton Cliffs RSPB	1991	0.235	0.213	0.241	0.097	0.590491	1	1
Bempton Cliffs RSPB	1992	0.298	0.272	0.273	0.119	0.465426	1	1
Bempton Cliffs RSPB	1993	0.253	0.230	0.251	0.103	0.465827	1	1
Bempton Cliffs RSPB	1994	0.291	0.265	0.270	0.116	0.490566	1	1
Bempton Cliffs RSPB	1995	0.316	0.289	0.282	0.126	0.475096	1	1
Bempton Cliffs RSPB	1996	0.269	0.245	0.259	0.109	0.604693	1	1
Bempton Cliffs RSPB	1997	0.336	0.308	0.292	0.133	0.210526	0	1
Bempton Cliffs RSPB	1998	0.278	0.253	0.263	0.112	0.436	1	1
Bempton Cliffs RSPB	1999	0.213	0.193	0.229	0.089	0.670068	1	1
Bempton Cliffs RSPB	2001	0.257	0.234	0.253	0.105	0.555901	1	1
Bempton Cliffs RSPB	2002	0.269	0.245	0.259	0.109	0.380866	1	1
Bempton Cliffs RSPB	2003	0.233	0.211	0.240	0.096	0.124579	0	1
Bempton Cliffs RSPB	2004	0.255	0.232	0.252	0.104	0.084665	0	0
Bempton Cliffs RSPB	2005	0.253	0.229	0.250	0.103	0.310231	1	1
Bempton Cliffs RSPB	2006	0.269	0.245	0.259	0.109	0.409385	1	1
Bempton Cliffs RSPB	2007	0.272	0.248	0.260	0.110	0.414557	1	1
Bempton Cliffs RSPB	2008	0.222	0.201	0.234	0.092	0.415361	1	1
Bempton Cliffs RSPB	2009	0.250	0.227	0.249	0.102	0.485455	1	1
Bempton Cliffs RSPB	2011	0.302	0.276	0.275	0.120	0.44564	1	1
Boddam to Collieston	1989	0.232	0.210	0.239	0.096	0.680851	1	1
Boddam to Collieston	1990	0.207	0.187	0.226	0.087	0.384401	1	1
Boddam to Collieston	1991	0.216	0.195	0.230	0.090	0.300373	1	1
Boddam to Collieston	1993	0.217	0.196	0.231	0.090	0.150519	0	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Boddam to Collieston	1994	0.255	0.231	0.251	0.104	0.244444	1	1
Boddam to Collieston	1995	0.289	0.264	0.269	0.116	0.409774	1	1
Boddam to Collieston	1996	0.246	0.223	0.247	0.101	0.049213	0	0
Boddam to Collieston	1997	0.242	0.219	0.245	0.099	0.084507	0	0
Boddam to Collieston	1998	0.226	0.205	0.236	0.093	0.119658	0	1
Boddam to Collieston	1999	0.183	0.165	0.212	0.078	0.065022	0	0
Boddam to Collieston	2000	0.233	0.211	0.240	0.096	0.408879	1	1
Boddam to Collieston	2001	0.235	0.213	0.241	0.097	0.451031	1	1
Boddam to Collieston	2002	0.244	0.222	0.246	0.100	0.22093	0	1
Boddam to Collieston	2003	0.210	0.190	0.228	0.088	0.365285	1	1
Boddam to Collieston	2004	0.214	0.193	0.229	0.089	0.354688	1	1
Boddam to Collieston	2005	0.210	0.190	0.227	0.088	0.540426	1	1
Boddam to Collieston	2006	0.231	0.209	0.239	0.095	0.359322	1	1
Boddam to Collieston	2007	0.215	0.195	0.230	0.090	0.18997	0	1
Boddam to Collieston	2008	0.210	0.190	0.227	0.088	0.185811	0	1
Boddam to Collieston	2009	0.229	0.208	0.238	0.095	0.532813	1	1
Boddam to Collieston	2010	0.237	0.215	0.242	0.097	0.335756	1	1
Coquet Island	1993	0.253	0.230	0.251	0.103	0.642857	1	1
Coquet Island	1994	0.291	0.265	0.270	0.116	0.477273	1	1
Coquet Island	1995	0.316	0.289	0.282	0.126	0.553191	1	1
Coquet Island	1996	0.269	0.245	0.259	0.109	0.611111	1	1
Coquet Island	1997	0.336	0.308	0.292	0.133	0.434426	1	1
Coquet Island	1998	0.278	0.253	0.263	0.112	0.284091	1	1
Coquet Island	1999	0.213	0.193	0.229	0.089	0.411765	1	1
Coquet Island	2000	0.268	0.244	0.258	0.108	0.55	1	1
Coquet Island	2001	0.257	0.234	0.253	0.105	0.651515	1	1
Coquet Island	2002	0.269	0.245	0.259	0.109	0.598765	1	1
Coquet Island	2003	0.233	0.211	0.240	0.096	0.845238	1	1
Coquet Island	2004	0.255	0.232	0.252	0.104	0.552941	1	1
Coquet Island	2005	0.253	0.229	0.250	0.103	0.53937	1	1
Coquet Island	2006	0.269	0.245	0.259	0.109	0.685185	1	1
Coquet Island	2007	0.272	0.248	0.260	0.110	0.483333	1	1
Coquet Island	2008	0.222	0.201	0.234	0.092	0.2	0	1
Coquet Island	2009	0.250	0.227	0.249	0.102	0.75	1	1
Coquet Island	2010	0.280	0.255	0.264	0.113	0.65	1	1
Coquet Island	2011	0.302	0.276	0.275	0.120	0.75	1	1
Costa Head	1986	0.252	0.229	0.250	0.103	0.5	1	1
Costa Head	1987	0.290	0.264	0.269	0.116	0.72459	1	1
Costa Head	1988	0.268	0.244	0.258	0.108	0.689759	1	1
Costa Head	1989	0.232	0.210	0.239	0.096	0.460526	1	1
Costa Head	1991	0.216	0.195	0.230	0.090	0.55	1	1
Costa Head	1998	0.226	0.205	0.236	0.093	0.575314	1	1
Costa Head	1999	0.183	0.165	0.212	0.078	0.549793	1	1
Costa Head	2000	0.233	0.211	0.240	0.096	0.550193	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Costa Head	2001	0.235	0.213	0.241	0.097	0.540284	1	1
Costa Head	2002	0.244	0.222	0.246	0.100	0.535176	1	1
Costa Head	2003	0.210	0.190	0.228	0.088	0.20082	1	1
Costa Head	2004	0.214	0.193	0.229	0.089	0	0	0
Costa Head	2005	0.210	0.190	0.227	0.088	0.34593	1	1
Costa Head	2006	0.231	0.209	0.239	0.095	0.243902	1	1
Costa Head	2007	0.215	0.195	0.230	0.090	0	0	0
Costa Head	2008	0.210	0.190	0.227	0.088	0	0	0
Costa Head	2009	0.229	0.208	0.238	0.095	0.333333	1	1
Costa Head	2011	0.226	0.204	0.236	0.093	0	0	0
Dunbar Coast and Harbour	1987	0.290	0.264	0.269	0.116	0.695015	1	1
Dunbar Coast and Harbour	1988	0.268	0.244	0.258	0.108	0.525	1	1
Dunbar Coast and Harbour	1989	0.232	0.210	0.239	0.096	0.789976	1	1
Dunbar Coast and Harbour	1990	0.207	0.187	0.226	0.087	0.470115	1	1
Dunbar Coast and Harbour	1991	0.216	0.195	0.230	0.090	0.349398	1	1
Dunbar Coast and Harbour	1992	0.240	0.217	0.243	0.098	0.765172	1	1
Dunbar Coast and Harbour	1993	0.217	0.196	0.231	0.090	0.169492	0	1
Dunbar Coast and Harbour	1994	0.255	0.231	0.251	0.104	0.319613	1	1
Dunbar Coast and Harbour	1995	0.289	0.264	0.269	0.116	0.474781	1	1
Dunbar Coast and Harbour	1996	0.246	0.223	0.247	0.101	0.364748	1	1
Dunbar Coast and Harbour	1997	0.242	0.219	0.245	0.099	0.475134	1	1
Dunbar Coast and Harbour	1998	0.226	0.205	0.236	0.093	0.345098	1	1
Dunbar Coast and Harbour	1999	0.183	0.165	0.212	0.078	0.374783	1	1
Dunbar Coast and Harbour	2000	0.233	0.211	0.240	0.096	0.570325	1	1
Dunbar Coast and Harbour	2001	0.235	0.213	0.241	0.097	0.389943	1	1
Dunbar Coast and Harbour	2002	0.244	0.222	0.246	0.100	0.480447	1	1
Dunbar Coast and Harbour	2003	0.210	0.190	0.228	0.088	0.41517	1	1
Dunbar Coast and Harbour	2004	0.214	0.193	0.229	0.089	0.284983	1	1
Dunbar Coast and Harbour	2005	0.210	0.190	0.227	0.088	0.479705	1	1
Dunbar Coast and Harbour	2007	0.215	0.195	0.230	0.090	0.305263	1	1
Dunbar Coast and Harbour	2009	0.229	0.208	0.238	0.095	0.481728	1	1
Dunbar Coast and Harbour	2010	0.237	0.215	0.242	0.097	0.310039	1	1
Eshaness	1986	0.252	0.229	0.250	0.103	0.317757	1	1
Eshaness	1987	0.290	0.264	0.269	0.116	0.325175	1	1
Eshaness	1988	0.268	0.244	0.258	0.108	0.225694	0	1
Eshaness	1989	0.232	0.210	0.239	0.096	0.310185	1	1
Eshaness	1990	0.207	0.187	0.226	0.087	0.25	1	1
Eshaness	1991	0.216	0.195	0.230	0.090	0.359756	1	1
Eshaness	1992	0.240	0.217	0.243	0.098	0.40429	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Eshaness	1993	0.217	0.196	0.231	0.090	0.020492	0	0
Eshaness	1994	0.255	0.231	0.251	0.104	0	0	0
Eshaness	1995	0.289	0.264	0.269	0.116	0	0	0
Eshaness	1996	0.246	0.223	0.247	0.101	0	0	0
Eshaness	1997	0.242	0.219	0.245	0.099	0	0	0
Eshaness	1998	0.226	0.205	0.236	0.093	0.033333	0	0
Eshaness	1999	0.183	0.165	0.212	0.078	0.090909	0	1
Fair Isle	1986	0.252	0.229	0.250	0.103	0.53	1	1
Fair Isle	1987	0.290	0.264	0.269	0.116	0.504841	1	1
Fair Isle	1988	0.268	0.244	0.258	0.108	0.039886	0	0
Fair Isle	1989	0.232	0.210	0.239	0.096	0.185004	0	1
Fair Isle	1990	0.207	0.187	0.226	0.087	0	0	0
Fair Isle	1991	0.216	0.195	0.230	0.090	0.444932	1	1
Fair Isle	1992	0.240	0.217	0.243	0.098	0.65	1	1
Fair Isle	1993	0.217	0.196	0.231	0.090	0.54012	1	1
Fair Isle	1994	0.255	0.231	0.251	0.104	0.614973	1	1
Fair Isle	1995	0.289	0.264	0.269	0.116	0.430207	1	1
Fair Isle	1996	0.246	0.223	0.247	0.101	0.61526	1	1
Fair Isle	1997	0.242	0.219	0.245	0.099	0.329944	1	1
Fair Isle	1998	0.226	0.205	0.236	0.093	0.075221	0	0
Fair Isle	1999	0.183	0.165	0.212	0.078	0.655126	1	1
Fair Isle	2000	0.233	0.211	0.240	0.096	0.540091	1	1
Fair Isle	2001	0.235	0.213	0.241	0.097	0.030216	0	0
Fair Isle	2002	0.244	0.222	0.246	0.100	0.240363	1	1
Fair Isle	2003	0.210	0.190	0.228	0.088	0	0	0
Fair Isle	2004	0.214	0.193	0.229	0.089	0	0	0
Fair Isle	2005	0.210	0.190	0.227	0.088	0.204604	1	1
Fair Isle	2006	0.231	0.209	0.239	0.095	0.12931	0	1
Fair Isle	2007	0.215	0.195	0.230	0.090	0.015748	0	0
Fair Isle	2008	0.210	0.190	0.227	0.088	0	0	0
Fair Isle	2009	0.229	0.208	0.238	0.095	0.208092	1	1
Fair Isle	2010	0.237	0.215	0.242	0.097	0.087349	0	0
Fair Isle	2011	0.226	0.204	0.236	0.093	0	0	0
Farne Islands	1987	0.377	0.348	0.312	0.148	0.565152	1	1
Farne Islands	1988	0.354	0.326	0.301	0.139	0.585161	1	1
Farne Islands	1989	0.273	0.249	0.261	0.110	0.684783	1	1
Farne Islands	1990	0.244	0.222	0.246	0.100	0.5	1	1
Farne Islands	1991	0.235	0.213	0.241	0.097	0.300158	1	1
Farne Islands	1992	0.298	0.272	0.273	0.119	0.540625	1	1
Farne Islands	1993	0.253	0.230	0.251	0.103	0.365503	1	1
Farne Islands	1994	0.291	0.265	0.270	0.116	0.439778	1	1
Farne Islands	1995	0.316	0.289	0.282	0.126	0.574751	1	1
Farne Islands	1996	0.269	0.245	0.259	0.109	0.63997	1	1
Farne Islands	1997	0.336	0.308	0.292	0.133	0.359868	1	1
Farne Islands	1998	0.278	0.253	0.263	0.112	0.164955	0	1
Farne Islands	1999	0.213	0.193	0.229	0.089	0.409801	1	1
Farne Islands	2000	0.268	0.244	0.258	0.108	0.490148	1	1
Farne Islands	2001	0.257	0.234	0.253	0.105	0.354972	1	1
Farne Islands	2002	0.269	0.245	0.259	0.109	0.395186	1	1
Farne Islands	2003	0.233	0.211	0.240	0.096	0.430251	1	1
Farne Islands	2004	0.255	0.232	0.252	0.104	0.050093	0	0
Farne Islands	2005	0.253	0.229	0.250	0.103	0.315254	1	1
Farne Islands	2006	0.269	0.245	0.259	0.109	0.285211	1	1
Farne Islands	2007	0.272	0.248	0.260	0.110	0.124587	0	1
Farne Islands	2008	0.222	0.201	0.234	0.092	0.163961	0	1
Farne Islands	2009	0.250	0.227	0.249	0.102	0.591906	1	1
Farne Islands	2010	0.280	0.255	0.264	0.113	0.575	1	1
Farne Islands	2011	0.302	0.276	0.275	0.120	0.496201	1	1
Foula	1986	0.252	0.229	0.250	0.103	0.439189	1	1
Foula	1988	0.268	0.244	0.258	0.108	0	0	0

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Foula	1989	0.232	0.210	0.239	0.096	0.155	0	1
Foula	1990	0.207	0.187	0.226	0.087	0.25	1	1
Foula	1991	0.216	0.195	0.230	0.090	0.375	1	1
Foula	1992	0.240	0.217	0.243	0.098	0.695	1	1
Foula	1993	0.217	0.196	0.231	0.090	0.46	1	1
Foula	1994	0.255	0.231	0.251	0.104	0.535714	1	1
Foula	1995	0.289	0.264	0.269	0.116	0.460352	1	1
Foula	1996	0.246	0.223	0.247	0.101	0.359621	1	1
Foula	1997	0.242	0.219	0.245	0.099	0.376712	1	1
Foula	1998	0.226	0.205	0.236	0.093	0.155556	0	1
Foula	1999	0.183	0.165	0.212	0.078	0.480114	1	1
Foula	2000	0.233	0.211	0.240	0.096	0.353383	1	1
Foula	2001	0.235	0.213	0.241	0.097	0.003448	0	0
Foula	2002	0.244	0.222	0.246	0.100	0.10687	0	1
Foula	2003	0.210	0.190	0.228	0.088	0	0	0
Foula	2004	0.214	0.193	0.229	0.089	0	0	0
Foula	2005	0.210	0.190	0.227	0.088	0.131068	0	1
Foula	2006	0.231	0.209	0.239	0.095	0.105042	0	1
Foula	2007	0.215	0.195	0.230	0.090	0.004587	0	0
Foula	2008	0.210	0.190	0.227	0.088	0	0	0
Foula	2009	0.229	0.208	0.238	0.095	0.193966	0	1
Foula	2010	0.237	0.215	0.242	0.097	0.018072	0	0
Fowlsheugh RSPB	1986	0.252	0.229	0.250	0.103	0.565	1	1
Fowlsheugh RSPB	1987	0.290	0.264	0.269	0.116	0.645349	1	1
Fowlsheugh RSPB	1988	0.268	0.244	0.258	0.108	0.5	1	1
Fowlsheugh RSPB	1989	0.232	0.210	0.239	0.096	0.644315	1	1
Fowlsheugh RSPB	1990	0.207	0.187	0.226	0.087	0.305241	1	1
Fowlsheugh RSPB	1993	0.217	0.196	0.231	0.090	0.189911	0	1
Fowlsheugh RSPB	1994	0.255	0.231	0.251	0.104	0.229567	0	1
Fowlsheugh RSPB	1995	0.289	0.264	0.269	0.116	0.350081	1	1
Fowlsheugh RSPB	1996	0.246	0.223	0.247	0.101	0.265152	1	1
Fowlsheugh RSPB	1997	0.242	0.219	0.245	0.099	0.185668	0	1
Fowlsheugh RSPB	1998	0.226	0.205	0.236	0.093	0.120192	0	1
Fowlsheugh RSPB	1999	0.183	0.165	0.212	0.078	0.224852	1	1
Fowlsheugh RSPB	2000	0.233	0.211	0.240	0.096	0.489458	1	1
Fowlsheugh RSPB	2001	0.235	0.213	0.241	0.097	0.280059	1	1
Fowlsheugh RSPB	2002	0.244	0.222	0.246	0.100	0.105085	0	1
Fowlsheugh RSPB	2003	0.210	0.190	0.228	0.088	0.549479	1	1
Fowlsheugh RSPB	2004	0.214	0.193	0.229	0.089	0.414729	1	1
Fowlsheugh RSPB	2005	0.210	0.190	0.227	0.088	0.445504	1	1
Fowlsheugh RSPB	2006	0.231	0.209	0.239	0.095	0.48017	1	1
Fowlsheugh RSPB	2007	0.215	0.195	0.230	0.090	0.380368	1	1
Fowlsheugh RSPB	2008	0.210	0.190	0.227	0.088	0.344776	1	1
Fowlsheugh RSPB	2009	0.229	0.208	0.238	0.095	0.575503	1	1
Fowlsheugh RSPB	2010	0.237	0.215	0.242	0.097	0.463415	1	1
Fowlsheugh RSPB	2011	0.226	0.204	0.236	0.093	0.670213	1	1
Gultak	1986	0.252	0.229	0.250	0.103	0.465438	1	1
Gultak	1987	0.290	0.264	0.269	0.116	0.5	1	1
Gultak	1988	0.268	0.244	0.258	0.108	0.565611	1	1
Gultak	1989	0.232	0.210	0.239	0.096	0.251969	1	1
Gultak	1990	0.207	0.187	0.226	0.087	0.345833	1	1
Gultak	1991	0.216	0.195	0.230	0.090	0.416667	1	1
Gultak	1992	0.240	0.217	0.243	0.098	0.699219	1	1
Gultak	1993	0.217	0.196	0.231	0.090	0.306122	1	1
Gultak	1994	0.255	0.231	0.251	0.104	0.397959	1	1
Gultak	1995	0.289	0.264	0.269	0.116	0.549451	1	1
Gultak	1996	0.246	0.223	0.247	0.101	0.538961	1	1
Gultak	1997	0.242	0.219	0.245	0.099	0.407692	1	1
Gultak	1998	0.226	0.205	0.236	0.093	0.459016	1	1
Gultak	1999	0.183	0.165	0.212	0.078	0.483607	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Gultak	2000	0.233	0.211	0.240	0.096	0.416667	1	1
Gultak	2001	0.235	0.213	0.241	0.097	0.233333	1	1
Gultak	2002	0.244	0.222	0.246	0.100	0.484375	1	1
Gultak	2003	0.210	0.190	0.228	0.088	0.348214	1	1
Gultak	2004	0.214	0.193	0.229	0.089	0	0	0
Gultak	2005	0.210	0.190	0.227	0.088	0.350877	1	1
Gultak	2006	0.231	0.209	0.239	0.095	0.296875	1	1
Gultak	2007	0.215	0.195	0.230	0.090	0	0	0
Gultak	2008	0.210	0.190	0.227	0.088	0	0	0
Gultak	2009	0.229	0.208	0.238	0.095	0.283019	1	1
Hermaness	1989	0.232	0.210	0.239	0.096	0.223757	1	1
Hermaness	1990	0.207	0.187	0.226	0.087	0.234637	1	1
Hermaness	1991	0.216	0.195	0.230	0.090	0.529412	1	1
Hermaness	1992	0.240	0.217	0.243	0.098	0.590361	1	1
Hermaness	1993	0.217	0.196	0.231	0.090	0.304688	1	1
Hermaness	1994	0.255	0.231	0.251	0.104	0.241379	1	1
Hermaness	1995	0.289	0.264	0.269	0.116	0.106195	0	0
Hermaness	1996	0.246	0.223	0.247	0.101	0.067308	0	0
Hermaness	1997	0.242	0.219	0.245	0.099	0.054688	0	0
Hermaness	1998	0.226	0.205	0.236	0.093	0.083333	0	0
Hermaness	1999	0.183	0.165	0.212	0.078	0.222222	1	1
Hermaness	2000	0.233	0.211	0.240	0.096	0.13964	0	1
Hermaness	2001	0.235	0.213	0.241	0.097	0	0	0
Hermaness	2002	0.244	0.222	0.246	0.100	0.244604	1	1
Hermaness	2003	0.210	0.190	0.228	0.088	0.021277	0	0
Hermaness	2004	0.214	0.193	0.229	0.089	0.070313	0	0
Hermaness	2005	0.210	0.190	0.227	0.088	0.218254	1	1
Hermaness	2006	0.231	0.209	0.239	0.095	0.188889	0	1
Hermaness	2008	0.210	0.190	0.227	0.088	0.055944	0	0
Hermaness	2009	0.229	0.208	0.238	0.095	0.310078	1	1
Hermaness	2010	0.237	0.215	0.242	0.097	0.05036	0	0
Isle of May	1986	0.252	0.229	0.250	0.103	0.665049	1	1
Isle of May	1987	0.290	0.264	0.269	0.116	0.544926	1	1
Isle of May	1988	0.268	0.244	0.258	0.108	0.410016	1	1
Isle of May	1989	0.232	0.210	0.239	0.096	0.555011	1	1
Isle of May	1990	0.207	0.187	0.226	0.087	0.08007	0	0
Isle of May	1991	0.216	0.195	0.230	0.090	0.134812	0	1
Isle of May	1992	0.240	0.217	0.243	0.098	0.305085	1	1
Isle of May	1993	0.217	0.196	0.231	0.090	0.034816	0	0
Isle of May	1994	0.255	0.231	0.251	0.104	0.145025	0	1
Isle of May	1995	0.289	0.264	0.269	0.116	0.200229	0	1
Isle of May	1996	0.246	0.223	0.247	0.101	0.280266	1	1
Isle of May	1997	0.242	0.219	0.245	0.099	0.200122	0	1
Isle of May	1998	0.226	0.205	0.236	0.093	0.010249	0	0
Isle of May	1999	0.183	0.165	0.212	0.078	0.099838	0	1
Isle of May	2000	0.233	0.211	0.240	0.096	0.485321	1	1
Isle of May	2001	0.235	0.213	0.241	0.097	0.305011	1	1
Isle of May	2002	0.244	0.222	0.246	0.100	0.234801	1	1
Isle of May	2003	0.210	0.190	0.228	0.088	0.385343	1	1
Isle of May	2004	0.214	0.193	0.229	0.089	0.144958	0	1
Isle of May	2005	0.210	0.190	0.227	0.088	0.39523	1	1
Isle of May	2006	0.231	0.209	0.239	0.095	0.23491	1	1
Isle of May	2007	0.215	0.195	0.230	0.090	0.114943	0	1
Isle of May	2008	0.210	0.190	0.227	0.088	0.089691	0	1
Isle of May	2009	0.229	0.208	0.238	0.095	0.351324	1	1
Isle of May	2010	0.237	0.215	0.242	0.097	0.145749	0	1
Isle of May	2011	0.226	0.204	0.236	0.093	0.435412	1	1
Lowestoft	1986	0.324	0.297	0.286	0.128	0.672222	1	1
Lowestoft	1987	0.377	0.348	0.312	0.148	0.78022	1	1
Lowestoft	1988	0.354	0.326	0.301	0.139	0.714953	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Lowestoft	1989	0.273	0.249	0.261	0.110	0.198864	0	1
Lowestoft	1990	0.244	0.222	0.246	0.100	0.578261	1	1
Lowestoft	1991	0.235	0.213	0.241	0.097	0.624204	1	1
Lowestoft	1992	0.298	0.272	0.273	0.119	0.573892	1	1
Lowestoft	1993	0.253	0.230	0.251	0.103	0.583832	1	1
Lowestoft	1994	0.291	0.265	0.270	0.116	0.605856	1	1
Lowestoft	1995	0.316	0.289	0.282	0.126	0.584942	1	1
Lowestoft	1996	0.269	0.245	0.259	0.109	0.565104	1	1
Lowestoft	1997	0.336	0.308	0.292	0.133	0.404605	1	1
Lowestoft	1998	0.278	0.253	0.263	0.112	0.404762	1	1
Lowestoft	1999	0.213	0.193	0.229	0.089	0.398551	1	1
Lowestoft	2000	0.268	0.244	0.258	0.108	0.49	1	1
Lowestoft	2001	0.257	0.234	0.253	0.105	0.464968	1	1
Lowestoft	2002	0.269	0.245	0.259	0.109	0.474194	1	1
Lowestoft	2003	0.233	0.211	0.240	0.096	0.630208	1	1
Lowestoft	2004	0.255	0.232	0.252	0.104	0.347826	1	1
Lowestoft	2005	0.253	0.229	0.250	0.103	0.363636	1	1
Lowestoft	2006	0.269	0.245	0.259	0.109	0.350649	1	1
Lowestoft	2007	0.272	0.248	0.260	0.110	0.461039	1	1
Lowestoft	2008	0.222	0.201	0.234	0.092	0.598726	1	1
Lowestoft	2009	0.250	0.227	0.249	0.102	0.5125	1	1
Lowestoft	2010	0.280	0.255	0.264	0.113	0.7	1	1
Lowestoft	2011	0.302	0.276	0.275	0.120	0.514205	1	1
Marwick Head	1986	0.252	0.229	0.250	0.103	0.491935	1	1
Marwick Head	1987	0.290	0.264	0.269	0.116	0.623188	1	1
Marwick Head	1988	0.268	0.244	0.258	0.108	0.5	1	1
Marwick Head	1989	0.232	0.210	0.239	0.096	0.509766	1	1
Marwick Head	1990	0.207	0.187	0.226	0.087	0.5	1	1
Marwick Head	1991	0.216	0.195	0.230	0.090	0.604	1	1
Marwick Head	1992	0.240	0.217	0.243	0.098	0.585069	1	1
Marwick Head	1993	0.217	0.196	0.231	0.090	0.464286	1	1
Marwick Head	1994	0.255	0.231	0.251	0.104	0.560811	1	1
Marwick Head	1995	0.289	0.264	0.269	0.116	0.634091	1	1
Marwick Head	1996	0.246	0.223	0.247	0.101	0.616162	1	1
Marwick Head	1997	0.242	0.219	0.245	0.099	0.765152	1	1
Marwick Head	1998	0.226	0.205	0.236	0.093	0.559659	1	1
Marwick Head	1999	0.183	0.165	0.212	0.078	0.554688	1	1
Marwick Head	2000	0.233	0.211	0.240	0.096	0.410798	1	1
Marwick Head	2001	0.235	0.213	0.241	0.097	0.509259	1	1
Marwick Head	2002	0.244	0.222	0.246	0.100	0.508824	1	1
Marwick Head	2003	0.210	0.190	0.228	0.088	0.34	1	1
Marwick Head	2004	0.214	0.193	0.229	0.089	0	0	0
Marwick Head	2005	0.210	0.190	0.227	0.088	0.380769	1	1
Marwick Head	2006	0.231	0.209	0.239	0.095	0.269697	1	1
Marwick Head	2007	0.215	0.195	0.230	0.090	0	0	0
Marwick Head	2008	0.210	0.190	0.227	0.088	0	0	0
Marwick Head	2009	0.229	0.208	0.238	0.095	0.326446	1	1
Marwick Head	2011	0.226	0.204	0.236	0.093	0	0	0
Mull Head _ cliff_nesters	1986	0.252	0.229	0.250	0.103	0.54	1	1
Mull Head _ cliff_nesters	1987	0.290	0.264	0.269	0.116	0.555147	1	1
Mull Head _ cliff_nesters	1988	0.268	0.244	0.258	0.108	0.50974	1	1
Mull Head _ cliff_nesters	1989	0.232	0.210	0.239	0.096	0.335366	1	1
Mull Head _ cliff_nesters	1990	0.207	0.187	0.226	0.087	0.521008	1	1
Mull Head _ cliff_nesters	1991	0.216	0.195	0.230	0.090	0.514768	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Mull Head _ cliff_nesters	1992	0.240	0.217	0.243	0.098	0.640562	1	1
Mull Head _ cliff_nesters	1993	0.217	0.196	0.231	0.090	0.443946	1	1
Mull Head _ cliff_nesters	1994	0.255	0.231	0.251	0.104	0.549528	1	1
Mull Head _ cliff_nesters	1995	0.289	0.264	0.269	0.116	0.640212	1	1
Mull Head _ cliff_nesters	1996	0.246	0.223	0.247	0.101	0.594937	1	1
Mull Head _ cliff_nesters	1997	0.242	0.219	0.245	0.099	0.614458	1	1
Mull Head _ cliff_nesters	1998	0.226	0.205	0.236	0.093	0.586207	1	1
Mull Head _ cliff_nesters	1999	0.183	0.165	0.212	0.078	0.569231	1	1
Mull Head _ cliff_nesters	2000	0.233	0.211	0.240	0.096	0.661616	1	1
Mull Head _ cliff_nesters	2001	0.235	0.213	0.241	0.097	0.574257	1	1
Mull Head _ cliff_nesters	2002	0.244	0.222	0.246	0.100	0.556034	1	1
Mull Head _ cliff_nesters	2003	0.210	0.190	0.228	0.088	0.360294	1	1
Mull Head _ cliff_nesters	2004	0.214	0.193	0.229	0.089	0	0	0
Mull Head _ cliff_nesters	2005	0.210	0.190	0.227	0.088	0.365979	1	1
Mull Head _ cliff_nesters	2006	0.231	0.209	0.239	0.095	0.227778	1	1
Mull Head _ cliff_nesters	2007	0.215	0.195	0.230	0.090	0	0	0
Mull Head _ cliff_nesters	2008	0.210	0.190	0.227	0.088	0	0	0
Mull Head _ cliff_nesters	2009	0.229	0.208	0.238	0.095	0	0	0
Newcastle to Seaton Sluice _ breeding success	1989	0.273	0.249	0.261	0.110	0.660804	1	1
Newcastle to Seaton Sluice _ breeding success	1990	0.244	0.222	0.246	0.100	0.580321	1	1
Newcastle to Seaton Sluice _ breeding success	1991	0.235	0.213	0.241	0.097	0.515086	1	1
Newcastle to Seaton Sluice _ breeding success	1992	0.298	0.272	0.273	0.119	0.589219	1	1
Newcastle to Seaton Sluice _ breeding success	1993	0.253	0.230	0.251	0.103	0.540493	1	1
Newcastle to Seaton Sluice _ breeding success	1994	0.291	0.265	0.270	0.116	0.505415	1	1
Newcastle to Seaton Sluice _ breeding success	1995	0.316	0.289	0.282	0.126	0.695122	1	1
Newcastle to Seaton Sluice _ breeding success	1996	0.269	0.245	0.259	0.109	0.614907	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Newcastle to Seaton Sluice _ breeding success	1997	0.336	0.308	0.292	0.133	0.375	1	1
Newcastle to Seaton Sluice _ breeding success	1998	0.278	0.253	0.263	0.112	0.44086	1	1
Newcastle to Seaton Sluice _ breeding success	1999	0.213	0.193	0.229	0.089	0.580357	1	1
Newcastle to Seaton Sluice _ breeding success	2000	0.268	0.244	0.258	0.108	0.654018	1	1
Newcastle to Seaton Sluice _ breeding success	2001	0.257	0.234	0.253	0.105	0.458974	1	1
Newcastle to Seaton Sluice _ breeding success	2002	0.269	0.245	0.259	0.109	0.619266	1	1
Newcastle to Seaton Sluice _ breeding success	2003	0.233	0.211	0.240	0.096	0.404412	1	1
Newcastle to Seaton Sluice _ breeding success	2004	0.255	0.232	0.252	0.104	0.360075	1	1
Newcastle to Seaton Sluice _ breeding success	2006	0.269	0.245	0.259	0.109	0.424437	1	1
Newcastle to Seaton Sluice _ breeding success	2007	0.272	0.248	0.260	0.110	0.524351	1	1
Newcastle to Seaton Sluice _ breeding success	2008	0.222	0.201	0.234	0.092	0.28479	1	1
Newcastle to Seaton Sluice _ breeding success	2009	0.250	0.227	0.249	0.102	0.4	1	1
Newcastle to Seaton Sluice _ breeding success	2010	0.280	0.255	0.264	0.113	0.518234	1	1
Noness	1996	0.246	0.223	0.247	0.101	0.430851	1	1
Noness	1997	0.242	0.219	0.245	0.099	0.121359	0	1
Noness	1998	0.226	0.205	0.236	0.093	0	0	0
Noness	1999	0.183	0.165	0.212	0.078	0.552941	1	1
Noness	2000	0.233	0.211	0.240	0.096	0.333333	1	1
Noness	2001	0.235	0.213	0.241	0.097	0	0	0
Noness	2002	0.244	0.222	0.246	0.100	0.037736	0	0
Noness	2003	0.210	0.190	0.228	0.088	0	0	0
Noness	2004	0.214	0.193	0.229	0.089	0	0	0
Noness	2005	0.210	0.190	0.227	0.088	0.365385	1	1
Noness	2006	0.231	0.209	0.239	0.095	0.357143	1	1
Noness	2007	0.215	0.195	0.230	0.090	0.076923	0	0
Noness	2008	0.210	0.190	0.227	0.088	0.102564	0	1
Noness	2009	0.229	0.208	0.238	0.095	0.294872	1	1
Noness	2010	0.237	0.215	0.242	0.097	0	0	0
Noness	2011	0.226	0.204	0.236	0.093	0	0	0
North Sutor Of CromartyCastlecraig	1990	0.207	0.187	0.226	0.087	0.418367	1	1
North Sutor Of CromartyCastlecraig	1991	0.216	0.195	0.230	0.090	0.442982	1	1
North Sutor Of CromartyCastlecraig	1992	0.240	0.217	0.243	0.098	0.320513	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
North Sutor Of CromartyCastlecraig	1993	0.217	0.196	0.231	0.090	0.469136	1	1
North Sutor Of CromartyCastlecraig	1994	0.255	0.231	0.251	0.104	0.478788	1	1
North Sutor Of CromartyCastlecraig	1995	0.289	0.264	0.269	0.116	0.590909	1	1
North Sutor Of CromartyCastlecraig	1996	0.246	0.223	0.247	0.101	0.248869	1	1
North Sutor Of CromartyCastlecraig	1997	0.242	0.219	0.245	0.099	0.130252	0	1
North Sutor Of CromartyCastlecraig	1998	0.226	0.205	0.236	0.093	0.459239	1	1
North Sutor Of CromartyCastlecraig	1999	0.183	0.165	0.212	0.078	0.26129	1	1
North Sutor Of CromartyCastlecraig	2000	0.233	0.211	0.240	0.096	0.266187	1	1
North Sutor Of CromartyCastlecraig	2001	0.235	0.213	0.241	0.097	0.366071	1	1
North Sutor Of CromartyCastlecraig	2002	0.244	0.222	0.246	0.100	0.216867	0	1
North Sutor Of CromartyCastlecraig	2003	0.210	0.190	0.228	0.088	0.09009	0	1
North Sutor Of CromartyCastlecraig	2004	0.214	0.193	0.229	0.089	0	0	0
North Sutor Of CromartyCastlecraig	2005	0.210	0.190	0.227	0.088	0	0	0
North Sutor Of CromartyCastlecraig	2006	0.231	0.209	0.239	0.095	0.055556	0	0
North Sutor Of CromartyCastlecraig	2007	0.215	0.195	0.230	0.090	0	0	0
North Sutor Of CromartyCastlecraig	2008	0.210	0.190	0.227	0.088	0	0	0
North Sutor Of CromartyCastlecraig	2009	0.229	0.208	0.238	0.095	0.225806	1	1
North Sutor Of CromartyCastlecraig	2010	0.237	0.215	0.242	0.097	0.44186	1	1
North Sutor Of CromartyCastlecraig	2011	0.226	0.204	0.236	0.093	0	0	0
Noss Whole Island	1986	0.252	0.229	0.250	0.103	0.289575	1	1
Noss Whole Island	1987	0.290	0.264	0.269	0.116	0.135492	0	1
Noss Whole Island	1988	0.268	0.244	0.258	0.108	0	0	0
Noss Whole Island	1989	0.232	0.210	0.239	0.096	0	0	0
Noss Whole Island	1990	0.207	0.187	0.226	0.087	0	0	0
Noss Whole Island	1991	0.216	0.195	0.230	0.090	0.084416	0	0
Noss Whole Island	1992	0.240	0.217	0.243	0.098	0.240331	1	1
Noss Whole Island	1993	0.217	0.196	0.231	0.090	0.174817	0	1
Noss Whole Island	1994	0.255	0.231	0.251	0.104	0.254845	1	1
Noss Whole Island	1995	0.289	0.264	0.269	0.116	0.239521	0	1
Noss Whole Island	1996	0.246	0.223	0.247	0.101	0.330426	1	1
Noss Whole Island	1997	0.242	0.219	0.245	0.099	0.034557	0	0
Noss Whole Island	1998	0.226	0.205	0.236	0.093	0	0	0
Noss Whole Island	1999	0.183	0.165	0.212	0.078	0.275058	1	1
Noss Whole Island	2000	0.233	0.211	0.240	0.096	0.159601	0	1
Noss Whole Island	2001	0.235	0.213	0.241	0.097	0	0	0
Noss Whole Island	2002	0.244	0.222	0.246	0.100	0.099462	0	0
Noss Whole Island	2003	0.210	0.190	0.228	0.088	0.004839	0	0
Noss Whole Island	2004	0.214	0.193	0.229	0.089	0.010294	0	0
Noss Whole Island	2005	0.210	0.190	0.227	0.088	0.225	1	1
Noss Whole Island	2006	0.231	0.209	0.239	0.095	0.330128	1	1
Noss Whole Island	2007	0.215	0.195	0.230	0.090	0.159274	0	1
Noss Whole Island	2008	0.210	0.190	0.227	0.088	0	0	0

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Noss Whole Island	2009	0.229	0.208	0.238	0.095	0.109848	0	1
Noss Whole Island	2010	0.237	0.215	0.242	0.097	0	0	0
Papa Westray _ North Hill RSPB	1989	0.232	0.210	0.239	0.096	0.310714	1	1
Papa Westray _ North Hill RSPB	1990	0.207	0.187	0.226	0.087	0.30566	1	1
Papa Westray _ North Hill RSPB	1991	0.216	0.195	0.230	0.090	0.379828	1	1
Papa Westray _ North Hill RSPB	1992	0.240	0.217	0.243	0.098	0.545643	1	1
Papa Westray _ North Hill RSPB	1993	0.217	0.196	0.231	0.090	0.535971	1	1
Papa Westray _ North Hill RSPB	1994	0.255	0.231	0.251	0.104	0.745989	1	1
Papa Westray _ North Hill RSPB	1995	0.289	0.264	0.269	0.116	0.473934	1	1
Papa Westray _ North Hill RSPB	1996	0.246	0.223	0.247	0.101	0.490854	1	1
Papa Westray _ North Hill RSPB	1997	0.242	0.219	0.245	0.099	0.268987	1	1
Papa Westray _ North Hill RSPB	1998	0.226	0.205	0.236	0.093	0.25	1	1
Papa Westray _ North Hill RSPB	1999	0.183	0.165	0.212	0.078	0.585443	1	1
Papa Westray _ North Hill RSPB	2000	0.233	0.211	0.240	0.096	0.513423	1	1
Papa Westray _ North Hill RSPB	2001	0.235	0.213	0.241	0.097	0.003378	0	0
Papa Westray _ North Hill RSPB	2002	0.244	0.222	0.246	0.100	0.516	1	1
Papa Westray _ North Hill RSPB	2003	0.210	0.190	0.228	0.088	0.019841	0	0
Papa Westray _ North Hill RSPB	2004	0.214	0.193	0.229	0.089	0	0	0
Papa Westray _ North Hill RSPB	2005	0.210	0.190	0.227	0.088	0.018293	0	0
Papa Westray _ North Hill RSPB	2006	0.231	0.209	0.239	0.095	0.025862	0	0
Papa Westray _ North Hill RSPB	2007	0.215	0.195	0.230	0.090	0	0	0
Papa Westray _ North Hill RSPB	2008	0.210	0.190	0.227	0.088	0	0	0
Papa Westray _ North Hill RSPB	2009	0.229	0.208	0.238	0.095	0	0	0
Papa Westray _ North Hill RSPB	2010	0.237	0.215	0.242	0.097	0	0	0
Papa Westray _ North Hill RSPB	2011	0.226	0.204	0.236	0.093	0	0	0
Row Head	1986	0.252	0.229	0.250	0.103	0.480501	1	1
Row Head	1987	0.290	0.264	0.269	0.116	0.619804	1	1
Row Head	1988	0.268	0.244	0.258	0.108	0.605495	1	1
Row Head	1989	0.232	0.210	0.239	0.096	0.47432	1	1
Row Head	1990	0.207	0.187	0.226	0.087	0.51548	1	1
Row Head	1991	0.216	0.195	0.230	0.090	0.639576	1	1
Row Head	1992	0.240	0.217	0.243	0.098	0.51	1	1
Row Head	1993	0.217	0.196	0.231	0.090	0.449597	1	1
Row Head	1994	0.255	0.231	0.251	0.104	0.585714	1	1
Row Head	1995	0.289	0.264	0.269	0.116	0.634091	1	1
Row Head	1996	0.246	0.223	0.247	0.101	0.605381	1	1
Row Head	1997	0.242	0.219	0.245	0.099	0.664063	1	1
Row Head	1998	0.226	0.205	0.236	0.093	0.550971	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Row Head	1999	0.183	0.165	0.212	0.078	0.504739	1	1
Row Head	2000	0.233	0.211	0.240	0.096	0.295053	1	1
Row Head	2001	0.235	0.213	0.241	0.097	0.486264	1	1
Row Head	2002	0.244	0.222	0.246	0.100	0.519704	1	1
Row Head	2003	0.210	0.190	0.228	0.088	0.245413	1	1
Row Head	2004	0.214	0.193	0.229	0.089	0	0	0
Row Head	2005	0.210	0.190	0.227	0.088	0.344538	1	1
Row Head	2006	0.231	0.209	0.239	0.095	0.230769	1	1
Row Head	2007	0.215	0.195	0.230	0.090	0	0	0
Row Head	2008	0.210	0.190	0.227	0.088	0	0	0
Row Head	2009	0.229	0.208	0.238	0.095	0.29	1	1
Saltburn Cliffs (Huntcliff)	1986	0.324	0.297	0.286	0.128	0.594828	1	1
Saltburn Cliffs (Huntcliff)	1987	0.377	0.348	0.312	0.148	0.516556	1	1
Saltburn Cliffs (Huntcliff)	1988	0.354	0.326	0.301	0.139	0.465625	1	1
Saltburn Cliffs (Huntcliff)	1989	0.273	0.249	0.261	0.110	0.5	1	1
Saltburn Cliffs (Huntcliff)	1990	0.244	0.222	0.246	0.100	0.504274	1	1
Saltburn Cliffs (Huntcliff)	1991	0.235	0.213	0.241	0.097	0.526178	1	1
Saltburn Cliffs (Huntcliff)	1992	0.298	0.272	0.273	0.119	0.575	1	1
Saltburn Cliffs (Huntcliff)	1993	0.253	0.230	0.251	0.103	0.444262	1	1
Saltburn Cliffs (Huntcliff)	1994	0.291	0.265	0.270	0.116	0.479853	1	1
Saltburn Cliffs (Huntcliff)	1995	0.316	0.289	0.282	0.126	0.425373	1	1
Saltburn Cliffs (Huntcliff)	1996	0.269	0.245	0.259	0.109	0.569196	1	1
Saltburn Cliffs (Huntcliff)	1997	0.336	0.308	0.292	0.133	0.099617	0	0
Saltburn Cliffs (Huntcliff)	1998	0.278	0.253	0.263	0.112	0.07598	0	0
Saltburn Cliffs (Huntcliff)	1999	0.213	0.193	0.229	0.089	0.380435	1	1
Saltburn Cliffs (Huntcliff)	2000	0.268	0.244	0.258	0.108	0.375	1	1
Saltburn Cliffs (Huntcliff)	2001	0.257	0.234	0.253	0.105	0.394118	1	1
Saltburn Cliffs (Huntcliff)	2002	0.269	0.245	0.259	0.109	0.335391	1	1
Saltburn Cliffs (Huntcliff)	2003	0.233	0.211	0.240	0.096	0.401099	1	1
Saltburn Cliffs (Huntcliff)	2004	0.255	0.232	0.252	0.104	0.130769	0	1
Saltburn Cliffs (Huntcliff)	2005	0.253	0.229	0.250	0.103	0.259109	1	1
Saltburn Cliffs (Huntcliff)	2006	0.269	0.245	0.259	0.109	0.409396	1	1
Saltburn Cliffs (Huntcliff)	2007	0.272	0.248	0.260	0.110	0.309365	1	1
Saltburn Cliffs (Huntcliff)	2008	0.222	0.201	0.234	0.092	0.17931	0	1
Sands Of Forvie	1989	0.232	0.210	0.239	0.096	0.411111	1	1
Sands Of Forvie	1990	0.207	0.187	0.226	0.087	0.228261	1	1
Sands Of Forvie	1991	0.216	0.195	0.230	0.090	0.164122	0	1
Sands Of Forvie	1992	0.240	0.217	0.243	0.098	0.510135	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Sands Of Forvie	1993	0.217	0.196	0.231	0.090	0.003676	0	0
Sands Of Forvie	1994	0.255	0.231	0.251	0.104	0.145631	0	1
Sands Of Forvie	1995	0.289	0.264	0.269	0.116	0.22314	0	1
Sands Of Forvie	1996	0.246	0.223	0.247	0.101	0.078804	0	0
Sands Of Forvie	1997	0.242	0.219	0.245	0.099	0.080808	0	0
Sands Of Forvie	1998	0.226	0.205	0.236	0.093	0.040541	0	0
Sands Of Forvie	1999	0.183	0.165	0.212	0.078	0.053435	0	0
Sands Of Forvie	2000	0.233	0.211	0.240	0.096	0.429825	1	1
Sands Of Forvie	2001	0.235	0.213	0.241	0.097	0.232143	1	1
Sands Of Forvie	2003	0.210	0.190	0.228	0.088	0.51087	1	1
Sands Of Forvie	2004	0.214	0.193	0.229	0.089	0.14375	0	1
Sands Of Forvie	2005	0.210	0.190	0.227	0.088	0.264463	1	1
Sands Of Forvie	2006	0.231	0.209	0.239	0.095	0.364964	1	1
Sands Of Forvie	2007	0.215	0.195	0.230	0.090	0.559829	1	1
Sands Of Forvie	2010	0.237	0.215	0.242	0.097	0.576667	1	1
St Abbs Head NNR	1987	0.377	0.348	0.312	0.148	0.511111	1	1
St Abbs Head NNR	1988	0.354	0.326	0.301	0.139	0.53	1	1
St Abbs Head NNR	1989	0.273	0.249	0.261	0.110	0.62008	1	1
St Abbs Head NNR	1990	0.244	0.222	0.246	0.100	0.304992	1	1
St Abbs Head NNR	1991	0.235	0.213	0.241	0.097	0.20483	0	1
St Abbs Head NNR	1992	0.298	0.272	0.273	0.119	0.515055	1	1
St Abbs Head NNR	1993	0.253	0.230	0.251	0.103	0.165196	0	1
St Abbs Head NNR	1994	0.291	0.265	0.270	0.116	0.269841	1	1
St Abbs Head NNR	1995	0.316	0.289	0.282	0.126	0.280206	0	1
St Abbs Head NNR	1996	0.269	0.245	0.259	0.109	0.530556	1	1
St Abbs Head NNR	1997	0.336	0.308	0.292	0.133	0.34019	1	1
St Abbs Head NNR	1998	0.278	0.253	0.263	0.112	0.135849	0	1
St Abbs Head NNR	1999	0.213	0.193	0.229	0.089	0.300752	1	1
St Abbs Head NNR	2000	0.268	0.244	0.258	0.108	0.399654	1	1
St Abbs Head NNR	2001	0.257	0.234	0.253	0.105	0.199262	0	1
St Abbs Head NNR	2002	0.269	0.245	0.259	0.109	0.165354	0	1
St Abbs Head NNR	2003	0.233	0.211	0.240	0.096	0.484293	1	1
St Abbs Head NNR	2004	0.255	0.232	0.252	0.104	0.134375	0	1
St Abbs Head NNR	2005	0.253	0.229	0.250	0.103	0.439394	1	1
St Abbs Head NNR	2006	0.269	0.245	0.259	0.109	0.136111	0	1
St Abbs Head NNR	2007	0.272	0.248	0.260	0.110	0.054124	0	0
St Abbs Head NNR	2008	0.222	0.201	0.234	0.092	0.059585	0	0
St Abbs Head NNR	2009	0.250	0.227	0.249	0.102	0.359281	1	1
St Abbs Head NNR	2010	0.280	0.255	0.264	0.113	0.239362	0	1
St Abbs Head NNR	2011	0.302	0.276	0.275	0.120	0.5	1	1
St Aldhelms Head _ Durlston Head	1991	0.235	0.213	0.241	0.097	0.107143	0	1
St Aldhelms Head _ Durlston Head	1992	0.298	0.272	0.273	0.119	0.209677	0	1
St Aldhelms Head _ Durlston Head	1993	0.253	0.230	0.251	0.103	0.25	1	1
St Aldhelms Head _ Durlston Head	1994	0.291	0.265	0.270	0.116	0.322368	1	1
St Aldhelms Head _ Durlston Head	1995	0.316	0.289	0.282	0.126	0.365079	1	1
St Aldhelms Head _ Durlston Head	1996	0.269	0.245	0.259	0.109	0.090164	0	0
St Aldhelms Head _ Durlston Head	1997	0.336	0.308	0.292	0.133	0.645161	1	1
St Aldhelms Head _ Durlston Head	1998	0.278	0.253	0.263	0.112	0.611111	1	1
St Aldhelms Head _ Durlston Head	1999	0.213	0.193	0.229	0.089	0.336957	1	1
St Aldhelms Head _ Durlston Head	2000	0.268	0.244	0.258	0.108	0.5	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
St Aldhelms Head _ Durlston Head	2001	0.257	0.234	0.253	0.105	0.327273	1	1
St Aldhelms Head _ Durlston Head	2002	0.269	0.245	0.259	0.109	0.40625	1	1
St Aldhelms Head _ Durlston Head	2003	0.233	0.211	0.240	0.096	0.36	1	1
St Aldhelms Head _ Durlston Head	2004	0.255	0.232	0.252	0.104	0.372549	1	1
St Aldhelms Head _ Durlston Head	2007	0.272	0.248	0.260	0.110	0.297297	1	1
St Aldhelms Head _ Durlston Head	2009	0.250	0.227	0.249	0.102	0.04878	0	0
Sumburgh Head	1986	0.252	0.229	0.250	0.103	0.269084	1	1
Sumburgh Head	1987	0.290	0.264	0.269	0.116	0.505376	1	1
Sumburgh Head	1988	0.268	0.244	0.258	0.108	0.004702	0	0
Sumburgh Head	1989	0.232	0.210	0.239	0.096	0.030702	0	0
Sumburgh Head	1990	0.207	0.187	0.226	0.087	0	0	0
Sumburgh Head	1991	0.216	0.195	0.230	0.090	0.313776	1	1
Sumburgh Head	1992	0.240	0.217	0.243	0.098	0.745342	1	1
Sumburgh Head	1993	0.217	0.196	0.231	0.090	0.620301	1	1
Sumburgh Head	1994	0.255	0.231	0.251	0.104	0.5	1	1
Sumburgh Head	1995	0.289	0.264	0.269	0.116	0.279221	1	1
Sumburgh Head	1996	0.246	0.223	0.247	0.101	0.40989	1	1
Sumburgh Head	1997	0.242	0.219	0.245	0.099	0.064554	0	0
Sumburgh Head	1998	0.226	0.205	0.236	0.093	0	0	0
Sumburgh Head	1999	0.183	0.165	0.212	0.078	0.394402	1	1
Sumburgh Head	2000	0.233	0.211	0.240	0.096	0.170418	0	1
Sumburgh Head	2001	0.235	0.213	0.241	0.097	0	0	0
Sumburgh Head	2002	0.244	0.222	0.246	0.100	0	0	0
Sumburgh Head	2003	0.210	0.190	0.228	0.088	0	0	0
Sumburgh Head	2004	0.214	0.193	0.229	0.089	0.004762	0	0
Sumburgh Head	2005	0.210	0.190	0.227	0.088	0.591304	1	1
Sumburgh Head	2006	0.231	0.209	0.239	0.095	0.351351	1	1
Sumburgh Head	2007	0.215	0.195	0.230	0.090	0.233577	1	1
Sumburgh Head	2008	0.210	0.190	0.227	0.088	0.004098	0	0
Sumburgh Head	2009	0.229	0.208	0.238	0.095	0.292969	1	1
Sumburgh Head	2010	0.237	0.215	0.242	0.097	0.059603	0	0
Sumburgh Head	2011	0.226	0.204	0.236	0.093	0	0	0
Westerwick	1987	0.290	0.264	0.269	0.116	0.015385	0	0
Westerwick	1988	0.268	0.244	0.258	0.108	0	0	0
Westerwick	1989	0.232	0.210	0.239	0.096	0	0	0
Westerwick	1990	0.207	0.187	0.226	0.087	0	0	0
Westerwick	1991	0.216	0.195	0.230	0.090	0.342593	1	1
Westerwick	1992	0.240	0.217	0.243	0.098	0.276786	1	1
Westerwick	1993	0.217	0.196	0.231	0.090	0.530612	1	1
Westerwick	1994	0.255	0.231	0.251	0.104	0.579365	1	1
Westerwick	1995	0.289	0.264	0.269	0.116	0.521739	1	1
Westerwick	1996	0.246	0.223	0.247	0.101	0.125	0	1
Westerwick	1997	0.242	0.219	0.245	0.099	0.136364	0	1
Westerwick	1998	0.226	0.205	0.236	0.093	0	0	0
Westerwick	1999	0.183	0.165	0.212	0.078	0.157895	0	1
Westerwick	2000	0.233	0.211	0.240	0.096	0	0	0
Westerwick	2001	0.235	0.213	0.241	0.097	0	0	0
Westerwick	2002	0.244	0.222	0.246	0.100	0	0	0
Westerwick	2003	0.210	0.190	0.228	0.088	0	0	0
Whale Wick to Sandwick	1993	0.217	0.196	0.231	0.090	0.392473	1	1
Whale Wick to Sandwick	1994	0.255	0.231	0.251	0.104	0.613821	1	1
Whale Wick to Sandwick	1995	0.289	0.264	0.269	0.116	0.351563	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Whale Wick to Sandwick	1996	0.246	0.223	0.247	0.101	0.416667	1	1
Whale Wick to Sandwick	1997	0.242	0.219	0.245	0.099	0.150327	0	1
Whale Wick to Sandwick	1998	0.226	0.205	0.236	0.093	0.018797	0	0
Whale Wick to Sandwick	1999	0.183	0.165	0.212	0.078	0.363309	1	1
Whale Wick to Sandwick	2000	0.233	0.211	0.240	0.096	0.173228	0	1
Whale Wick to Sandwick	2001	0.235	0.213	0.241	0.097	0.013514	0	0
Whale Wick to Sandwick	2002	0.244	0.222	0.246	0.100	0.090909	0	0
Whale Wick to Sandwick	2003	0.210	0.190	0.228	0.088	0.051948	0	0
Whale Wick to Sandwick	2004	0.214	0.193	0.229	0.089	0.175676	0	1
Whale Wick to Sandwick	2005	0.210	0.190	0.227	0.088	0.336957	1	1
Whale Wick to Sandwick	2006	0.231	0.209	0.239	0.095	0.447619	1	1
Whale Wick to Sandwick	2007	0.215	0.195	0.230	0.090	0.36036	1	1
Whale Wick to Sandwick	2008	0.210	0.190	0.227	0.088	0.076389	0	0
Whale Wick to Sandwick	2009	0.229	0.208	0.238	0.095	0.635802	1	1
Whale Wick to Sandwick	2010	0.237	0.215	0.242	0.097	0.006757	0	0
Whale Wick to Sandwick	2011	0.226	0.204	0.236	0.093	0	0	0

Table A 2. Predicted values, lower confidence intervals and whether the recorded success per egg (breeding success/2) has achieved the target value (1=achieved; 0=not achieved) specified by the fixed-slope model and the random-slope model for each colony of the CS sub-region for each year.

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Ailsa Craig	1987	0.228	0.189	0.207	0.001	0.333	0	1
Ailsa Craig	1988	0.223	0.184	0.209	0.001	0.030	0	1
Ailsa Craig	1989	0.219	0.181	0.210	0.001	0.084	0	1
Ailsa Craig	1990	0.196	0.161	0.219	0.001	0.119	0	1
Ailsa Craig	1991	0.196	0.161	0.219	0.001	0.220	0	1
Ailsa Craig	1992	0.216	0.178	0.211	0.001	0.291	0	1
Ailsa Craig	1993	0.209	0.172	0.214	0.001	0.366	1	1
Ailsa Craig	1994	0.219	0.181	0.210	0.001	0.403	1	1
Ailsa Craig	1995	0.232	0.192	0.206	0.001	0.781	1	1
Ailsa Craig	1996	0.218	0.180	0.211	0.001	0.864	1	1
Ailsa Craig	1997	0.215	0.178	0.212	0.001	0.736	1	1
Ailsa Craig	1998	0.217	0.180	0.211	0.001	0.829	1	1
Ailsa Craig	1999	0.194	0.159	0.220	0.001	1.208	1	1
Ailsa Craig	2000	0.212	0.176	0.213	0.001	0.820	1	1
Ailsa Craig	2001	0.215	0.178	0.212	0.001	0.267	0	1
Ailsa Craig	2002	0.217	0.179	0.211	0.001	0.442	1	1
Ailsa Craig	2003	0.200	0.164	0.218	0.001	0.432	1	1
Ailsa Craig	2004	0.205	0.169	0.216	0.001	0.652	1	1
Ailsa Craig	2005	0.201	0.165	0.217	0.001	0.643	1	1
Ailsa Craig	2006	0.206	0.170	0.215	0.001	0.138	0	1
Ailsa Craig	2007	0.211	0.174	0.213	0.001	0.086	0	1
Ailsa Craig	2008	0.197	0.162	0.219	0.001	0.300	0	1
Ailsa Craig	2009	0.201	0.165	0.217	0.001	0.439	1	1
Ailsa Craig	2010	0.210	0.173	0.214	0.001	0.530	1	1
Ailsa Craig	2011	0.219	0.181	0.210	0.001	0.656	1	1
Bardsey Island	1987	0.228	0.189	0.207	0.001	1.011	1	1
Bardsey Island	1988	0.223	0.184	0.209	0.001	0.854	1	1
Bardsey Island	1989	0.219	0.181	0.210	0.001	0.481	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Bardsey Island	1990	0.196	0.161	0.219	0.001	0.138	0	1
Bardsey Island	1991	0.196	0.161	0.219	0.001	0.000	0	0
Bardsey Island	1993	0.209	0.172	0.214	0.001	0.038	0	1
Bardsey Island	1994	0.219	0.181	0.210	0.001	0.268	0	1
Bardsey Island	1995	0.232	0.192	0.206	0.001	0.388	1	1
Bardsey Island	1996	0.218	0.180	0.211	0.001	1.220	1	1
Bardsey Island	1997	0.215	0.178	0.212	0.001	0.762	1	1
Bardsey Island	1998	0.217	0.180	0.211	0.001	1.017	1	1
Bardsey Island	1999	0.194	0.159	0.220	0.001	1.251	1	1
Bardsey Island	2000	0.212	0.176	0.213	0.001	1.119	1	1
Bardsey Island	2001	0.215	0.178	0.212	0.001	1.128	1	1
Bardsey Island	2002	0.217	0.179	0.211	0.001	1.120	1	1
Bardsey Island	2003	0.200	0.164	0.218	0.001	1.121	1	1
Bardsey Island	2004	0.205	0.169	0.216	0.001	0.601	1	1
Bardsey Island	2005	0.201	0.165	0.217	0.001	0.551	1	1
Bardsey Island	2006	0.206	0.170	0.215	0.001	0.679	1	1
Bardsey Island	2007	0.211	0.174	0.213	0.001	0.691	1	1
Bardsey Island	2011	0.219	0.181	0.210	0.001	0.516	1	1
Canna & Sanday	1986	0.215	0.178	0.212	0.001	0.278	0	1
Canna & Sanday	1987	0.228	0.189	0.207	0.001	0.500	1	1
Canna & Sanday	1988	0.223	0.184	0.209	0.001	0.190	0	1
Canna & Sanday	1989	0.219	0.181	0.210	0.001	0.749	1	1
Canna & Sanday	1990	0.196	0.161	0.219	0.001	0.969	1	1
Canna & Sanday	1991	0.196	0.161	0.219	0.001	0.640	1	1
Canna & Sanday	1992	0.216	0.178	0.211	0.001	0.420	1	1
Canna & Sanday	1993	0.209	0.172	0.214	0.001	0.421	1	1
Canna & Sanday	1994	0.219	0.181	0.210	0.001	0.859	1	1
Canna & Sanday	1995	0.232	0.192	0.206	0.001	0.801	1	1
Canna & Sanday	1996	0.218	0.180	0.211	0.001	0.949	1	1
Canna & Sanday	1997	0.215	0.178	0.212	0.001	0.949	1	1
Canna & Sanday	1998	0.217	0.180	0.211	0.001	1.000	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Canna & Sanday	1999	0.194	0.159	0.220	0.001	0.639	1	1
Canna & Sanday	2000	0.212	0.176	0.213	0.001	0.491	1	1
Canna & Sanday	2001	0.215	0.178	0.212	0.001	0.821	1	1
Canna & Sanday	2002	0.217	0.179	0.211	0.001	0.601	1	1
Canna & Sanday	2003	0.200	0.164	0.218	0.001	1.000	1	1
Canna & Sanday	2004	0.205	0.169	0.216	0.001	0.801	1	1
Canna & Sanday	2005	0.201	0.165	0.217	0.001	0.000	0	0
Canna & Sanday	2006	0.206	0.170	0.215	0.001	0.460	1	1
Canna & Sanday	2007	0.211	0.174	0.213	0.001	0.349	1	1
Canna & Sanday	2008	0.197	0.162	0.219	0.001	0.000	0	0
Canna & Sanday	2009	0.201	0.165	0.217	0.001	1.241	1	1
Canna & Sanday	2010	0.210	0.173	0.214	0.001	0.788	1	1
Canna & Sanday	2011	0.219	0.181	0.210	0.001	0.669	1	1
Glen Maye	1992	0.216	0.178	0.211	0.001	0.000	0	0
Glen Maye	1993	0.209	0.172	0.214	0.001	0.390	1	1
Glen Maye	1994	0.219	0.181	0.210	0.001	0.730	1	1
Glen Maye	1995	0.232	0.192	0.206	0.001	0.000	0	0
Glen Maye	1996	0.218	0.180	0.211	0.001	0.000	0	0
Glen Maye	1997	0.215	0.178	0.212	0.001	0.150	0	1
Glen Maye	1998	0.217	0.180	0.211	0.001	0.010	0	1
Glen Maye	1999	0.194	0.159	0.220	0.001	0.550	1	1
Glen Maye	2000	0.212	0.176	0.213	0.001	0.750	1	1
Glen Maye	2001	0.215	0.178	0.212	0.001	0.930	1	1
Glen Maye	2002	0.217	0.179	0.211	0.001	0.180	0	1
Glen Maye	2004	0.205	0.169	0.216	0.001	0.000	0	0
Glen Maye	2005	0.201	0.165	0.217	0.001	0.330	0	1
Great Orme	1989	0.219	0.181	0.210	0.001	0.201	0	1
Great Orme	1990	0.196	0.161	0.219	0.001	0.503	1	1
Great Orme	1991	0.196	0.161	0.219	0.001	0.328	1	1
Great Orme	1992	0.216	0.178	0.211	0.001	0.528	1	1
Great Orme	1993	0.209	0.172	0.214	0.001	0.338	0	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Great Orme	1994	0.219	0.181	0.210	0.001	0.452	1	1
Great Orme	1995	0.232	0.192	0.206	0.001	0.949	1	1
Great Orme	1996	0.218	0.180	0.211	0.001	0.989	1	1
Great Orme	1997	0.215	0.178	0.212	0.001	0.450	1	1
Great Orme	1998	0.217	0.180	0.211	0.001	0.601	1	1
Great Orme	1999	0.194	0.159	0.220	0.001	0.691	1	1
Great Orme	2000	0.212	0.176	0.213	0.001	0.799	1	1
Great Orme	2001	0.215	0.178	0.212	0.001	0.379	1	1
Great Orme	2002	0.217	0.179	0.211	0.001	0.379	1	1
Great Orme	2003	0.200	0.164	0.218	0.001	0.540	1	1
Great Orme	2004	0.205	0.169	0.216	0.001	0.493	1	1
Great Orme	2005	0.201	0.165	0.217	0.001	0.311	0	1
Great Orme	2006	0.206	0.170	0.215	0.001	0.278	0	1
Great Orme	2007	0.211	0.174	0.213	0.001	0.000	0	0
Green Bridge	1991	0.196	0.161	0.219	0.001	0.120	0	1
Green Bridge	1992	0.216	0.178	0.211	0.001	0.129	0	1
Green Bridge	1993	0.209	0.172	0.214	0.001	0.381	1	1
Green Bridge	1994	0.219	0.181	0.210	0.001	0.500	1	1
Green Bridge	1995	0.232	0.192	0.206	0.001	0.368	0	1
Green Bridge	1996	0.218	0.180	0.211	0.001	0.202	0	1
Green Bridge	1997	0.215	0.178	0.212	0.001	0.218	0	1
Green Bridge	1998	0.217	0.180	0.211	0.001	0.217	0	1
Green Bridge	1999	0.194	0.159	0.220	0.001	0.820	1	1
Green Bridge	2000	0.212	0.176	0.213	0.001	0.738	1	1
Green Bridge	2001	0.215	0.178	0.212	0.001	0.126	0	1
Green Bridge	2002	0.217	0.179	0.211	0.001	0.000	0	0
Green Bridge	2003	0.200	0.164	0.218	0.001	0.242	0	1
Green Bridge	2004	0.205	0.169	0.216	0.001	0.079	0	1
Green Bridge	2005	0.201	0.165	0.217	0.001	0.167	0	1
Green Bridge	2006	0.206	0.170	0.215	0.001	0.000	0	0
Green Bridge	2007	0.211	0.174	0.213	0.001	0.000	0	0

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Green Bridge	2008	0.197	0.162	0.219	0.001	0.000	0	0
Green Bridge	2009	0.201	0.165	0.217	0.001	0.296	0	1
Green Bridge	2010	0.210	0.173	0.214	0.001	0.478	1	1
Handa	1986	0.215	0.178	0.212	0.001	1.091	1	1
Handa	1988	0.223	0.184	0.209	0.001	0.691	1	1
Handa	1989	0.219	0.181	0.210	0.001	1.530	1	1
Handa	1990	0.196	0.161	0.219	0.001	1.349	1	1
Handa	1991	0.196	0.161	0.219	0.001	1.540	1	1
Handa	1992	0.216	0.178	0.211	0.001	1.219	1	1
Handa	1993	0.209	0.172	0.214	0.001	1.269	1	1
Handa	1994	0.219	0.181	0.210	0.001	1.538	1	1
Handa	1995	0.232	0.192	0.206	0.001	1.468	1	1
Handa	1996	0.218	0.180	0.211	0.001	1.589	1	1
Handa	1997	0.215	0.178	0.212	0.001	1.380	1	1
Handa	1998	0.217	0.180	0.211	0.001	1.431	1	1
Handa	1999	0.194	0.159	0.220	0.001	1.220	1	1
Handa	2000	0.212	0.176	0.213	0.001	1.100	1	1
Handa	2001	0.215	0.178	0.212	0.001	1.250	1	1
Handa	2002	0.217	0.179	0.211	0.001	1.280	1	1
Handa	2003	0.200	0.164	0.218	0.001	0.880	1	1
Handa	2004	0.205	0.169	0.216	0.001	1.110	1	1
Handa	2005	0.201	0.165	0.217	0.001	0.219	0	1
Handa	2006	0.206	0.170	0.215	0.001	0.009	0	1
Handa	2007	0.211	0.174	0.213	0.001	0.009	0	1
Handa	2008	0.197	0.162	0.219	0.001	0.000	0	0
Handa	2009	0.201	0.165	0.217	0.001	0.932	1	1
Handa	2010	0.210	0.173	0.214	0.001	0.350	1	1
Handa	2011	0.219	0.181	0.210	0.001	1.187	1	1
Hirta	1986	0.215	0.178	0.212	0.001	0.521	1	1
Hirta	1987	0.228	0.189	0.207	0.001	0.761	1	1
Hirta	1988	0.223	0.184	0.209	0.001	0.648	1	1
Hirta	1989	0.219	0.181	0.210	0.001	0.601	1	1
Hirta	1990	0.196	0.161	0.219	0.001	0.290	0	1
Hirta	1991	0.196	0.161	0.219	0.001	0.843	1	1
Hirta	1992	0.216	0.178	0.211	0.001	0.381	1	1
Hirta	1993	0.209	0.172	0.214	0.001	0.360	1	1
Hirta	1994	0.219	0.181	0.210	0.001	0.740	1	1
Hirta	1996	0.218	0.180	0.211	0.001	0.620	1	1
Hirta	1997	0.215	0.178	0.212	0.001	0.009	0	1
Hirta	1998	0.217	0.180	0.211	0.001	0.379	1	1
Hirta	1999	0.194	0.159	0.220	0.001	0.220	0	1
Hirta	2000	0.212	0.176	0.213	0.001	0.379	1	1
Hirta	2001	0.215	0.178	0.212	0.001	0.250	0	1
Hirta	2002	0.217	0.179	0.211	0.001	0.209	0	1
Hirta	2003	0.200	0.164	0.218	0.001	0.311	0	1
Hirta	2004	0.205	0.169	0.216	0.001	0.372	1	1
Hirta	2005	0.201	0.165	0.217	0.001	0.321	0	1
Hirta	2006	0.206	0.170	0.215	0.001	0.538	1	1
Hirta	2007	0.211	0.174	0.213	0.001	0.238	0	1
Hirta	2008	0.197	0.162	0.219	0.001	0.015	0	1
Hirta	2009	0.201	0.165	0.217	0.001	0.196	0	1
Hirta	2011	0.219	0.181	0.210	0.001	0.128	0	1
Ramsey Isl	1996	0.218	0.180	0.211	0.001	0.519	1	1
Ramsey Isl	1997	0.215	0.178	0.212	0.001	0.850	1	1

Colony	Year	Predicted (fixed-slope model)	Lower (fixed-slope model)	Predicted (random-slope model)	Lower (random-slope model)	Success per egg	Achieved (fixed-slope model)	Achieved (random-slope model)
Ramsey Isl	2000	0.212	0.176	0.213	0.001	1.090	1	1
Ramsey Isl	2001	0.215	0.178	0.212	0.001	0.000	0	0
Ramsey Isl	2002	0.217	0.179	0.211	0.001	0.880	1	1
Ramsey Isl	2003	0.200	0.164	0.218	0.001	0.758	1	1
Ramsey Isl	2004	0.205	0.169	0.216	0.001	0.000	0	0
Ramsey Isl	2005	0.201	0.165	0.217	0.001	0.733	1	1
Ramsey Isl	2006	0.206	0.170	0.215	0.001	0.289	0	1
Ramsey Isl	2007	0.211	0.174	0.213	0.001	0.000	0	0
Ramsey Isl	2008	0.197	0.162	0.219	0.001	0.507	1	1
Ramsey Isl	2009	0.201	0.165	0.217	0.001	0.659	1	1
Ramsey Isl	2010	0.210	0.173	0.214	0.001	0.280	0	1
Ramsey Isl	2011	0.219	0.181	0.210	0.001	0.154	0	1
Skomer	1986	0.215	0.178	0.212	0.001	0.447	1	1
Skomer	1987	0.228	0.189	0.207	0.001	0.971	1	1
Skomer	1988	0.223	0.184	0.209	0.001	0.760	1	1
Skomer	1989	0.219	0.181	0.210	0.001	0.610	1	1
Skomer	1990	0.196	0.161	0.219	0.001	0.530	1	1
Skomer	1991	0.196	0.161	0.219	0.001	0.870	1	1
Skomer	1992	0.216	0.178	0.211	0.001	0.470	1	1
Skomer	1993	0.209	0.172	0.214	0.001	0.660	1	1
Skomer	1994	0.219	0.181	0.210	0.001	0.900	1	1
Skomer	1995	0.232	0.192	0.206	0.001	0.940	1	1
Skomer	1996	0.218	0.180	0.211	0.001	0.450	1	1
Skomer	1997	0.215	0.178	0.212	0.001	0.680	1	1
Skomer	1998	0.217	0.180	0.211	0.001	0.800	1	1
Skomer	1999	0.194	0.159	0.220	0.001	0.950	1	1
Skomer	2000	0.212	0.176	0.213	0.001	0.780	1	1
Skomer	2001	0.215	0.178	0.212	0.001	0.210	0	1
Skomer	2002	0.217	0.179	0.211	0.001	0.610	1	1
Skomer	2003	0.200	0.164	0.218	0.001	0.530	1	1
Skomer	2004	0.205	0.169	0.216	0.001	0.470	1	1
Skomer	2005	0.201	0.165	0.217	0.001	1.010	1	1
Skomer	2006	0.206	0.170	0.215	0.001	0.889	1	1
Skomer	2007	0.211	0.174	0.213	0.001	0.390	1	1
Skomer	2008	0.197	0.162	0.219	0.001	0.550	1	1
Skomer	2009	0.201	0.165	0.217	0.001	0.646	1	1
Skomer	2010	0.210	0.173	0.214	0.001	0.705	1	1
Skomer	2011	0.219	0.181	0.210	0.001	0.541	1	1