Galloper Wind Farm Project

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Alde-Ore Estuary SPA Lesser Black-Backed Gull
Stochastic Population Viability Analysis

Galloper Wind Farm Limited

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CONTENTS

1 INTRODUCTION

1.1.1 This note summarises the approach to, and results of, Population Viability Analysis (PVA) modelling for the breeding lesser black-backed gull population of the Alde-Ore Estuary SPA.

1.1.2 This modelling exercise has been undertaken to inform the assessment of the potential for an adverse effect on the Alde-Ore Estuary SPA that may arise from the proposed Galloper Wind Farm (GWF) project.

1.1.3 During the Environmental Impact Assessment (EIA) and Habitat Regulations Assessment (HRA) for GWF, the potential for mortality of lesser black-backed gull arising from the proposed operation of the wind farm was identified. Furthermore, it was assumed that a proportion of those predicted collisions could involve birds associated with the breeding population of the SPA.

1.1.4 Pre-application consultations with JNCC, Natural England and non-statutory consultees, undertaken in connection with the application for GWF, did not lead to clear advice on the level of mortality which might lead to a significant effect on the breeding lesser black-backed gull interest feature. GWL therefore agreed to undertake PVA modelling (within the pre-application phase) to better understand the dynamics of this population and the likely effects of any additional mortality that may arise from wind farm operation.

1.1.5 Feedback on initial modelling was received during pre-application consultation and this has led to further modelling work, and it is this further modelling which forms the subject of this note.

1.1.6 This note considers a 'closed' population model, i.e. without immigration / emigration, and therefore its outcomes should be considered precautionary. It is intended that the extent of immigration to be considered in the final decision on adverse effect will be the subject of ongoing consultation with relevant consultees prior to the Plannning Inspectorate 'first response date' (16th July 2012).

1.1.7 The purpose of this note is to:

a. Summarise discussions about the approach to PVA modelling

b. Describe the methods and assumptions used in the PVA model

c. Present the results of PVA modelling

d. Assist in progressing the determination of what may constitute an adverse effect on the integrity of the Alde-Ore Estuary SPA

1.1 Background

1.1.8 PVA modelling was undertaken during the EIA process, the results of which are described in the Environmental Statement (ES) [Doc Ref 5.2.11], Chapter 11, paragraphs 11.7.91 to 11.7.99, and the Habitats Regulations Assessment (HRA) Report [Doc Ref 6.3], Section 7.8. The model described in those documents is 'deterministic', that is, reflecting a system in which no randomness is involved in the development of future states of the system. A deterministic model will thus always produce the same output from a given starting condition or initial state. Since there was little information in this case on how demographic rates of the SPA population vary between years, this model type was chosen for assessment purposes.

1.1.9 The deterministic growth rate modelled was thus the average population growth expected if it is not possible or realistic to account for 'stochastic' random processes. To simulate the impact of additional mortality on the population, with respect to population growth rate and the predicted population size after 25 years, a fixed number of breeding adults was removed from the population at each time step.

1.1.10 During recent consultations, JNCC and Natural England advised an approach to PVA modelling that incorporates variation in demographic parameters, and so recommended the use of a stochastic, as opposed to deterministic model.

1.1.11 In addition it was further advised by JNCC and Natural England that:

1. sensitivity/elasticity analysis should to be conducted
2. the outputs of modelling should be probabilistic in nature
3. the model should disentangle collision risk modelling from population modelling – that is, the model should simply consider the effects of a range of 'additional mortality' levels above the assumed background rate of mortality within the population

1.1.12 The RSPB have been consulted on the approach to PVA modelling and their opinions have been taken into consideration. The RSPB generally agreed with the recommendations of Natural England and JNCC but also noted that there is presently no long-term commitment for the site managers (RSPB and National Trust) to undertake management aimed at returning the breeding lesser black-backed gull population to previous levels.

1.2 Favourable condition of the SPA population

1.2.1 A key factor in the consideration of the likely effect of any additional mortality on the integrity of a population that is a feature of a Natura 2000 site is the extent to which such mortality may lead to a change in its condition. GWFL sought advice from Natural England on the revised Conservation Objectives of the Alde-Ore Estuary SPA (in light of an SPA lesser black-backed gull population crash in 2001 after the original citation at c. 21,000 pairs), and what would now constitute a Favourable Condition for the breeding lesser black-backed gull interest feature.

1.2.2 Natural England confirmed [email from Sam Stewart on 04.04.2012] that the Conservation Objective for lesser black-backed gull at the SPA is:

"To maintain the designated species in favourable condition, which is defined in part in relation to their population attributes. Favourable condition is defined at this site in terms of the following site-specific standards:

a. Maintain population within acceptable limits (Generic threshold system to be adopted).

b. Where the limits of natural fluctuations are not known, maintain the population above 75% of that at designation - loss of 25% or more unacceptable.

c. Counts or estimates of numbers of breeding pairs."

1.2.3 Natural England confirmed [email from Sam Stewart on 30.05.2012] a population target of 14,074 lesser black backed gull pairs based on a 4 year mean at the time of designation (1994-1997) derived from the JNCC Seabird Monitoring Programme database. Natural England also advised that the setting of a population target was derived through a standard procedure- 4-5 year mean at the time of a citation update in March 1998.

1.2.4 In light of the most recent estimate of the breeding population at Orford Ness and Havergate Island (circa 1,600 pairs), Natural England further confirmed [in the same email from Sam Stewart on 30.05.2012] that the status of this population is "unfavourable declining".

1.2.5 In the 1990s, the lesser black-backed gull population exhibited the ability to grow rapidly, to a size beyond the current population target (Figure 1). Natural England consider it a possibility that targeted site management may facilitate population recovery to again reach the population target of 14,074 pairs: *"Those experienced in the management of this site suggest that it remains possible that more effective management of certain local factors such as mammalian predators, human disturbance and vegetation growth may facilitate population recovery."* [email from Sam Stewart 30.05.12].

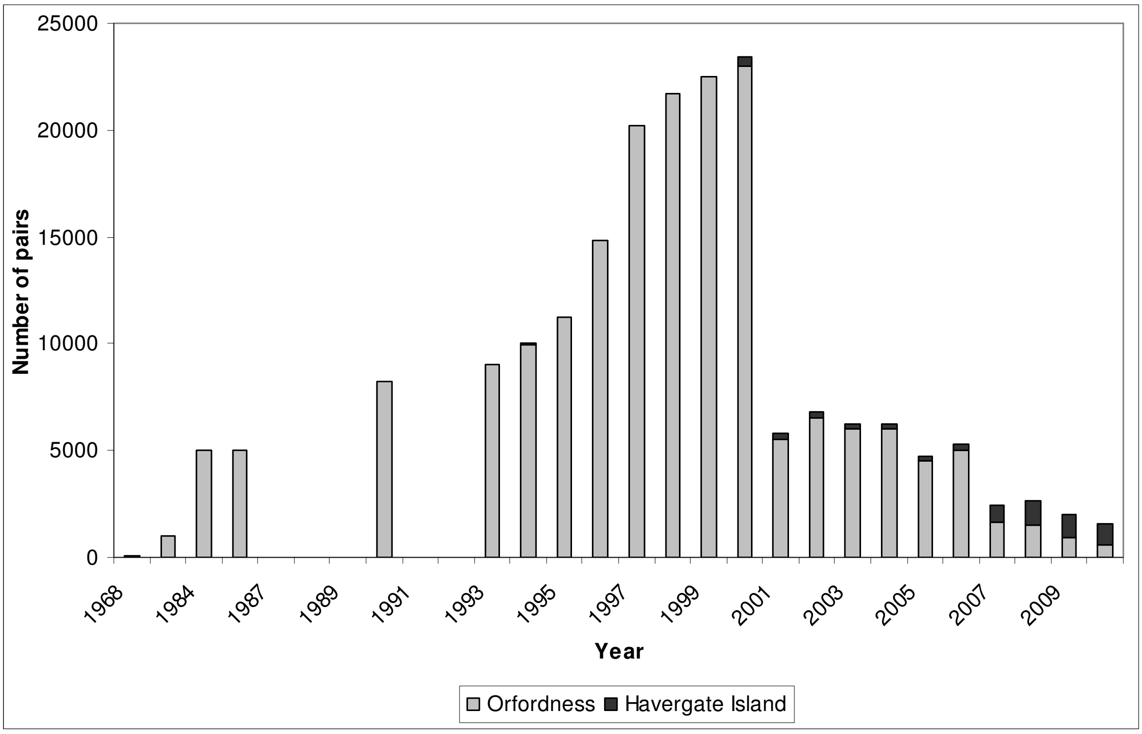


Figure 1: Lesser black-backed gull population counts within the Alde-Ore Estuary SPA. Data obtained from Landguard Bird Observatory and RSPB records for Orfordness and Havergate Island respectively.

2 METHODS

2.1 Model Parameters

2.1.1 To alleviate any outstanding concerns on the modelling process and chosen parameters, a method statement on the stochastic model was provided to JNCC and Natural England in January 2012, and this is provided in Appendix 1. Also contained in this method statement was a presentation and rationale behind the input parameters chosen for the modelling. This is included in Appendix 2. The following text provides a summary of the methodology used.

2.1.2 The stochastic model produced is bespoke for the SPA population, and follows best practice methods (e.g. selection of appropriate probability distributions for survival and reproduction; Morris & Doak 2002[1]). The model is generally based on the same demographic data used in the deterministic model, and presented previously in the EIA and HRA reports, with the addition of estimates of the variance on these rates. The modelling has also been informed by the lesser black-backed gull model presented by Poot et al. (2011[2]), although certain

[1] Morris, W.F. & Doak, D.F. (2002) Quantitative Conservation Biology: theory and practice of population viability analysis. Sinauer Assoc. MA

[2] Poot, M.J.M., van Horssen, P.W., Collier, M.P., Lensink, R. and Dirksen, S. (2011). Effect studies Offshore Wind Egmond aan Zee: cumulative effects on seabirds: A modelling approach to estimate effects on population levels in seabirds. Bureau Waardenburg bv report commissioned by: Noordzeewind.

methodological aspects of their approach are not considered appropriate for the present purposes (see Appendix 1 for further details).

2.1.3 It is important to note that the modelling has been based on a ‘closed’ population, i.e. one where it is assumed that there is no immigration or emigration to and from the colony. Based on past experience of the colony this is considered to be highly conservative. In fact, it is implicit in Natural England’s advice on the conservation objectives for the Alde-Ore Estuary SPA that immigration will be required if the population is to return to favourable condition.

2.1.4 The lesser black-backed gull population was modelled on an annual time step, using a five age class model: 0-1, 1-2, 2-3, 3-4, 4+. It was assumed that only the final age class breeds, and that the model structure is that of a post-breeding census. The same survival rate was used for the first 4 age classes, although each was generated independently during simulations.

2.1.5 The ratio of these age classes in the stochastic model is representative of the proportion of sub-adults to adults (approximately 7 : 93) recorded within the GWF site on boat-based surveys during the breeding season. In actuality, juveniles and younger immatures may also collide with turbines, which would in turn reduce the proportion of collisions assigned to adult birds, and so this stance is seen as precautionary.

2.1.6 Environmental stochasticity is modelled using the standard deviations as listed in Table 1 of Appendix 2. Survival rates are drawn from a beta distribution, and brood sizes from a lognormal distribution. These distributions were used as they generate random numbers with appropriate characteristics (e.g. survival between 0 and 1, and brood sizes greater than zero).

2.1.7 Demographic stochasticity on survival is modelled using a binomial process, whereby the number of individuals surviving from one time step to the next is estimated using a binomial function which uses as inputs the number of individuals available at time step 1 and the randomly generated survival rate (as described above).

2.1.8 The difference between environmental and demographic stochasticity can be thought of as follows: environmental stochasticity generates random values for the probability of survival from one time step to the next. Demographic stochasticity generates random numbers of individuals which survive from one time step to the next for any given survival probability. Thus environmental stochasticity models vary environments (e.g. weather effects) while demographic stochasticity models chance effects due to the population size.

2.1.9 As agreed with JNCC and Natural England all rates are modelled as density independent. Additional mortality is applied to the sub-adult and adult age classes in proportion to their presence in the population (approx.7:93). Values for additional mortality used in the model were from 0 to 400 at intervals of 25.

2.1.10 The value for additional mortality defined at the outset of a simulation was used to calculate the proportional mortality for the sub-adult and adult age classes. For example, if the additional mortality is set at 100 individuals, the estimated sub-adult and adult proportions of the initial population that this number represents are calculated. In this manner the additional mortality is converted into a proportion, which is then applied across all years of the simulation. Thus, additional mortality remains at the same proportional level relative to the population size throughout the simulation.

2.1.11 The average population growth rate, and upper and lower 95% confidence intervals are calculated across all simulations (5,000). Matrix based population models such as this one tend to produce unrepresentative outputs for the first few time-steps. To prevent this influencing the results, the growth rate was estimated between the 5th and final year of each simulation.

2.1.12 The probability of population decline below specific thresholds, defined as percentages of the initial population size, is calculated as the proportion of simulations which decline below the threshold at any point during the simulation.

2.2 Modelling scenarios

2.2.1 The modelling process has been based on an attempt to most accurately reflect the lesser black-backed gull SPA population from the time construction of GWF would commence, onwards through the operational period of the wind farm, i.e. it takes into account any reasonably foreseeable changes due to factors such as reduced disturbance and predation, increased food availability and improved nesting habitat which in turn is likely to affect adult survival and productivity (these site-specific influences are described in more detail in the ES and HRA reports).

2.2.2 It is considered that this process will most accurately reflect the conditions that will exist at the time of wind farm construction. The prediction of the baseline in this way is consistent with paragraph 3.3 of the IEEM (2010[3]) guidance which states that "*The conditions that define the baseline need to be carefully considered. This is because the baseline may differ from conditions that exist at the time an assessment is made. In order to determine this, it is necessary to try to predict any changes that will alter conditions prior to the start of the proposed construction and subsequent to it*".

2.2.3 The primary focus of this assessment concerns a predicted 'Management' scenario, which is based on Natural England's envisaged requirements for the population to meet their SPA population target. Natural England has advocated an "*adaptive management approach*" in order to achieve favourable condition for the site [email from Dr. James Bussell, 07.06.12]. This would generally "*identify site-specific causes of unfavourable condition then implement*

[3] IEEM (2010) Guidelines for Ecological Impact Assessment in Britain and Ireland: Marine and Coastal. . Institute of Ecology and Environmental Management, London.

management measures to address these" and would initially help move the population from 'unfavourable declining' to 'unfavourable recovering' by influencing site-specific population dynamics, such as productivity.

2.2.4 In addition, two alternative scenarios ('Historic' and 'Baseline') consider the past, and existing levels of site management within the Alde-Ore Estuary SPA respectively.

2.2.5 These three scenarios were chosen based on the realistic range of parameters recorded within the SPA and other comparable lesser black-backed gull colonies, and have also been influenced by Natural England's and RSPB's advice during consultation on their respective views of the lesser black-backed gull SPA population.

'Management' scenario

2.2.6 Values of productivity and adult lesser black-backed gull survival recorded at the Alde-Ore Estuary SPA and other colonies have been selected that are considered representative of parameters where targeted and realistic SPA management measures (e.g. vegetation clearance and maintenance, predator and human access restrictions around gull colonies) have been implemented (see Appendix 2, Table 1 for parameters and rationale). This situation would produce conditions that are conducive to increased survival and productivity, and ultimately the growth of the colony (adult survival rate of 0.95 and productivity rate of 1.00 chicks per pair).

2.2.7 It is these measures that would play a significant role in taking the SPA population towards the levels of growth required to meet Natural England's ambitions for favourable condition of the site as part of the 'adaptive management approach'. It should be noted that the Management scenario does not reflect an overly-optimistic view of the demographics of this population. It is representative of the conditions that should exist in the absence of external influences such as increased mammalian predation and it also represents the conditions that will need to exist if the SPA population is to return to the growth rates that have existed in the past.

[NB this scenario correlates with the 'High' scenario used in the previous deterministic PVA model]

'Baseline' scenario

2.2.8 Input parameter values are designed to represent the scenario at present, where SPA management measures (not targeted at lesser black-backed gull specifically), including predator control, water level and habitat management and human disturbance restrictions, have been recently implemented to protect Annex I species, and gulls have also benefitted from these improvements, albeit indirectly (see Appendix 2, Table 1 for values and rationale). This represents a relatively typical UK colony, with improved but more natural rates of predation, disturbance and habitat quality compared to historic levels (adult survival rate of 0.93 and productivity rate of 0.80 chicks per pair).

[NB this scenario correlates with the 'Medium' scenario used in the previous deterministic PVA model]

'Historic' scenario

2.2.9 Low values of adult survival and productivity are taken from the SPA and scientific literature and are considered to represent the recent past baseline situation within the SPA, where predation and disturbance levels were high, average survival and productivity rates are low, and results of recently-implemented SPA management measures (not targeted at lesser black-backed gull) have not been recorded (see Appendix 2, Table 1 for values and rationale). This represents in effect a status quo situation, if the SPA had continued with lack of management intervention, and remained in 'unfavourable, declining' conservation status (adult survival rate of 0.90 and productivity rate of 0.45 chicks per pair).

2.2.10 The parameters selected are similar to, but slightly more conservative than, those recommended by RSPB (email from Amy Crossley, dated 11 April 2012) stating that "*the adult survival and productivity rates that could be achieved and reliably maintained for the SPA are 0.90 and 0.5-0.6 respectively*"[4].

[NB this scenario correlates with the 'Low' scenario used in the previous deterministic PVA model, as outlined in the ES Chapter and HRA reports]

3 RESULTS

3.1.1 For each of the scenarios outlined above, the results of the PVA modelling are presented in a similar manner. Firstly, mean growth rates (number of pairs) are shown (with 95% confidence intervals), based on the input parameters selected, and also when considering additional mortality, using a range of harvest rates (up to 400 individuals).

3.1.2 Secondly the probability of a decline in the population (between 0-25% population reduction) is presented at a similar range of harvest rates. Finally, a

[4] It is taken that the 'productivity' values recommended by RSPB are consistent with the ones used for this modelling (i.e. mean brood size, equating to the number of chicks per pair). Technically in population models an overall, per individual adult 'productivity rate' is usually generated (to avoid confusion this is often called a 'fecundity rate'). This is a product of adult survival (only surviving birds can breed), proportion of birds which breed and mean brood size. The mean brood size is also divided by two as the model is based on individuals, not pairs (in other words 1 chick per pair is only 0.5 chicks per individual). In this case it is however assumed that RSPB's productivity rates refer to the 'mean brood size' which is the equivalent parameter to the ones previously provided to RSPB by GWFL for the various scenarios, rather than overall per individual adult productivity.

graph is shown that predicts the changes in the number of SPA pairs over a 25 year period (with 95% confidence intervals).

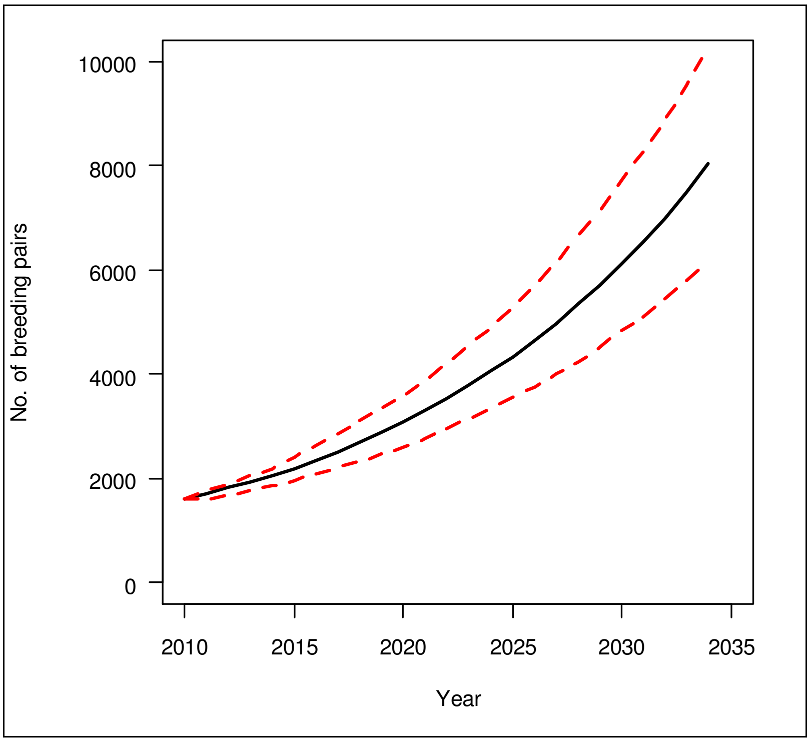
Management scenario

3.1.3 The 'Management' scenario presents a 'closed model' situation based on Natural England's views on favourable condition of the site, and the required adaptive management approach to meet such targets. Note that no timescale for meeting the lesser black-backed gull population target has been defined by Natural England.

3.1.4 The model shows that with targeted management, growth will occur over a 25 year period from the current 1,603 pairs to approximately 8,000 pairs, thereby reversing the general trend of decline in pairs this century (Figure 2). The original deterministic model similarly predicted that the population would grow to around 6,700 pairs over this timeframe.

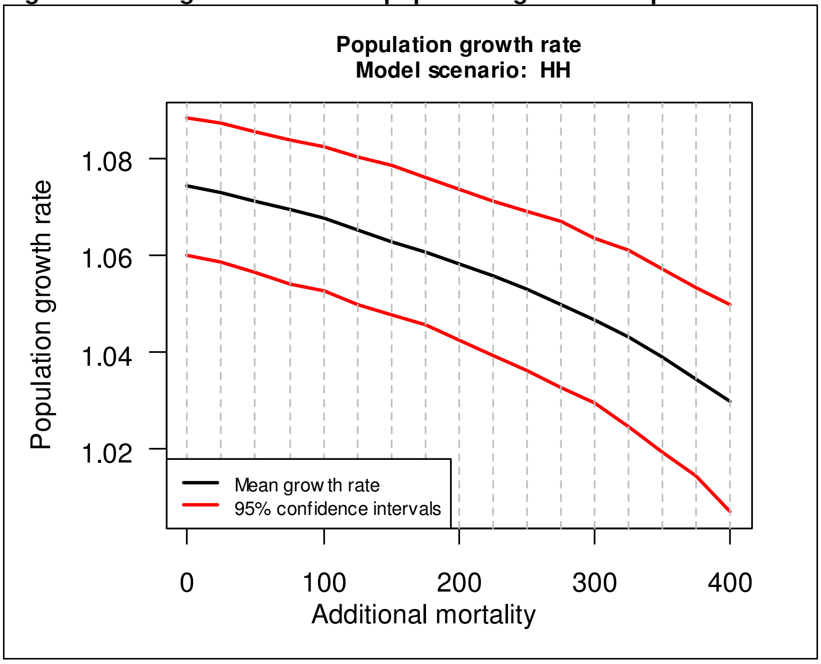
3.1.5 In relation to Natural England's population target for favourable condition, this falls short over the wind farm's lifespan, although it is important to note that a precautionary view of zero immigration has been assumed, which would be a vital part of the population reaching 14,000 pairs. If this was considered to be a more realistic 'open' population, then immigration would result in the overall population further increasing over this timeframe, if conditions become relatively more favourable compared to other sites, due to SPA management improvements targeted towards lesser black-backed gull.

Figure 2: 'Management' scenario population change



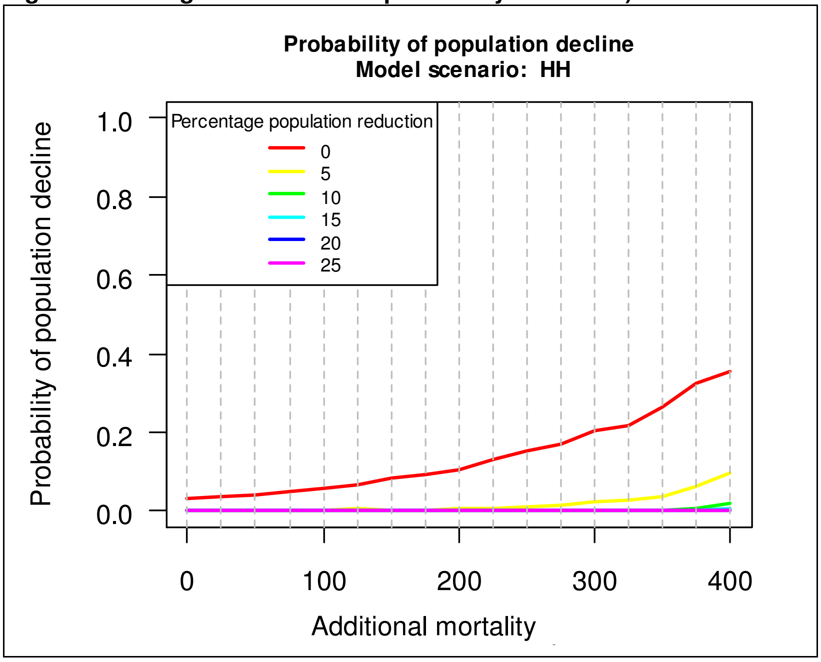
3.1.6 The model predicts that average population growth is positive for all additional mortality rates tested and that 95% of simulations have positive growth at all rates tested (Figure 3).

Figure 3: 'Management' scenario population growth rate predictions



3.1.7 The probability of the SPA population declining below the starting size (red line, Figure 4) increases from approximately 3% with no additional mortality to 15% at 250 additional deaths. The probability of the SPA population declining by 5% (yellow line) increases from 0.1% with no additional mortality to 1% with 250 additional deaths, and 9.5% at 400 additional deaths.

Figure 4: 'Management' scenario probability of decline)

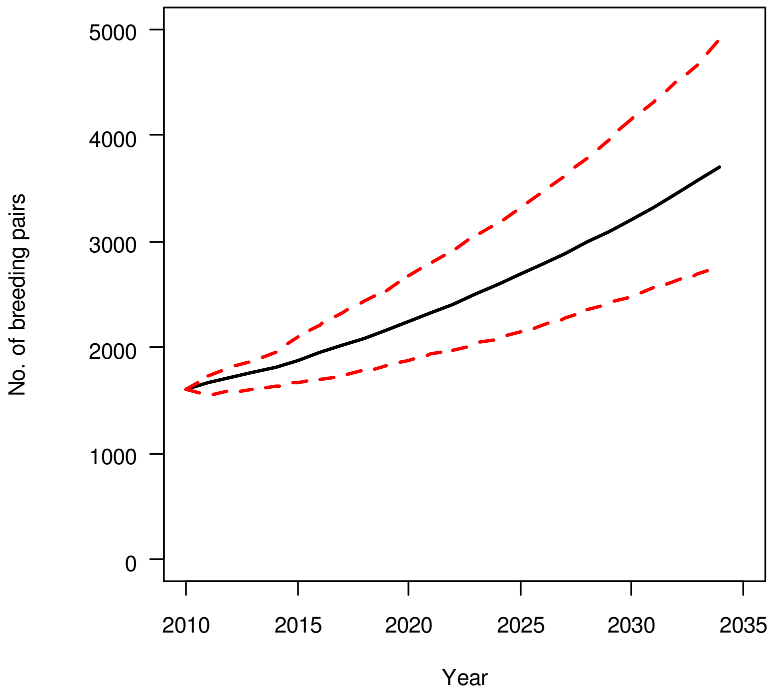


Baseline scenario

3.1.8 The model shows that growth will occur over a 25 year period, albeit at a lower rate than under the Management scenario, from the current 1,603 pairs to approximately 3,400 pairs (Figure 5). This is in line with early evidence (including 2012 data) of current habitat improvements within the SPA, although not targeted at lesser black-backed gull, with an increase in numbers at Havergate Island colonies, and a stabilisation of numbers at Orfordness, compared to the early 21st century. The original deterministic model similarly predicted that the population would grow to around 3,200 pairs over this timeframe.

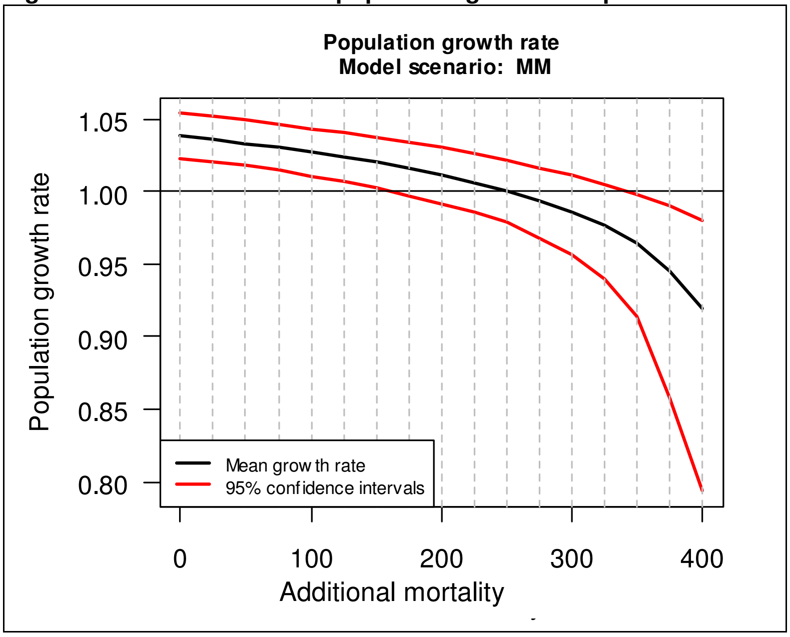
3.1.9 In relation to Natural England's population target for favourable condition, this falls quite considerably short, although as before, immigration has not been taken into account. Based on the modelling, it is likely that without immigration it would be over 50 years before this target is met.

Figure 5: 'Baseline' scenario population change



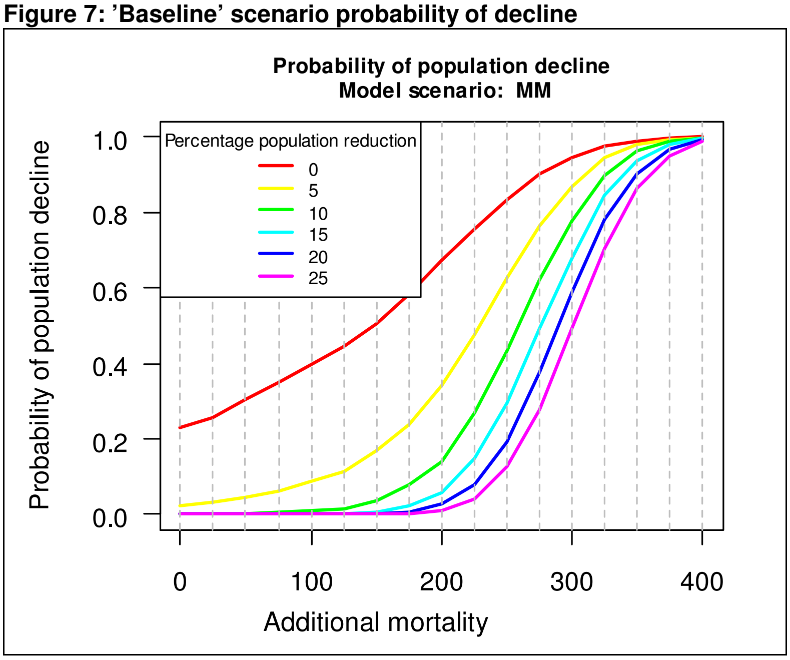
3.1.10 The stochastic model predicts positive growth on average, until additional mortality reaches approximately 250 individuals during the breeding season (Figure 6). Based on the lower confidence level, 95% of simulations have positive growth on average until additional mortality reaches around 160 individuals.

Figure 6: 'Baseline' scenario population growth rate predictions



3.1.11 The probability of the SPA population declining below the starting size (red line, Figure 7) increases from approximately 23% with no additional mortality to approximately 83% at 250 additional deaths. At a 67% probability of any decline, it is predicted that 200 deaths are required. The probability of the SPA population declining by 5% (yellow line) increases from approximately 2% with no additional mortality to 62% with 250 additional deaths.

Figure 7: 'Baseline' scenario probability of decline



Historic scenario

3.1.12 The results from the ‘Historic’ model presented in Figure 8 show a decline in numbers of pairs, as would be expected if none of the SPA management measures had been implemented to date, and adult survival and productivity was relatively low. This is closely representative of the outcome for the population when considering RSPB’s parameters, with the same adult survival rate and a slightly higher productivity rate of 0.5-0.6 chicks per pair, which somewhat reduces the long-term decline.

3.1.13 This provides a moderate level of fit to the Alde-Ore Estuary SPA population over the period 2001-2010 (Figure 9). It was considered unsuitable to model over a longer timeframe due to the catastrophic decline in numbers in the 2001 breeding season from over 23,000 pairs to 5,790 in 2001, as this would be unrepresentative of the colony’s current population dynamics and attempting to capture this in the model would be of little value for the current purposes.

3.1.14 Generally the model provides reasonable predictions for the population decline seen during the first five years, or the last four, but fails to capture the marked drop in breeding pairs between 2006-7. This highlights a difficulty when attempting to predict (or validate) trends in species such as lesser black-backed gull where populations may be prone to bursts of immigration or emigration, and do not form part of a ‘closed’ population. The reason for the further decline between 2006-7 is unclear but may well be related to emigration from the colony due to intense predation (there was almost total breeding failure at Orfordness in 2006, but also in 2007), or potentially more subtle cumulative effects of various influences from previous years.

Figure 8: 'Historic' scenario population change

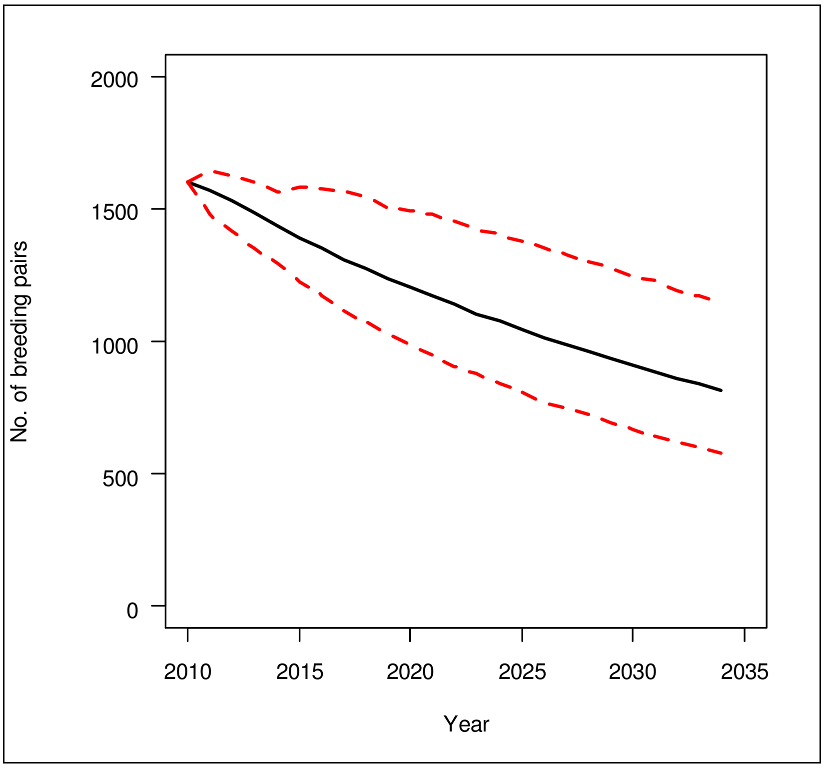
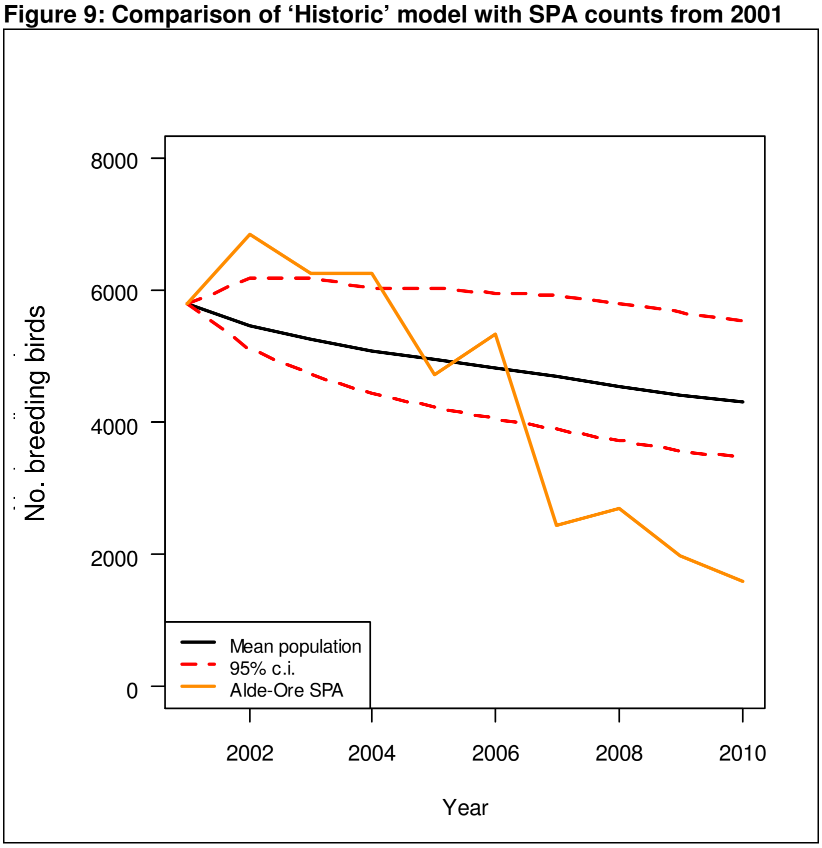


Figure 9: Comparison of 'Historic' model with SPA counts from 2001



3.1.15 As would be expected in this scenario, any additional mortality further reduces the population growth rate (Figure 10), and the probability of decline is 1.0 regardless of additional mortality level (Figure 11).

Figure 10: 'Historic' scenario population growth rate

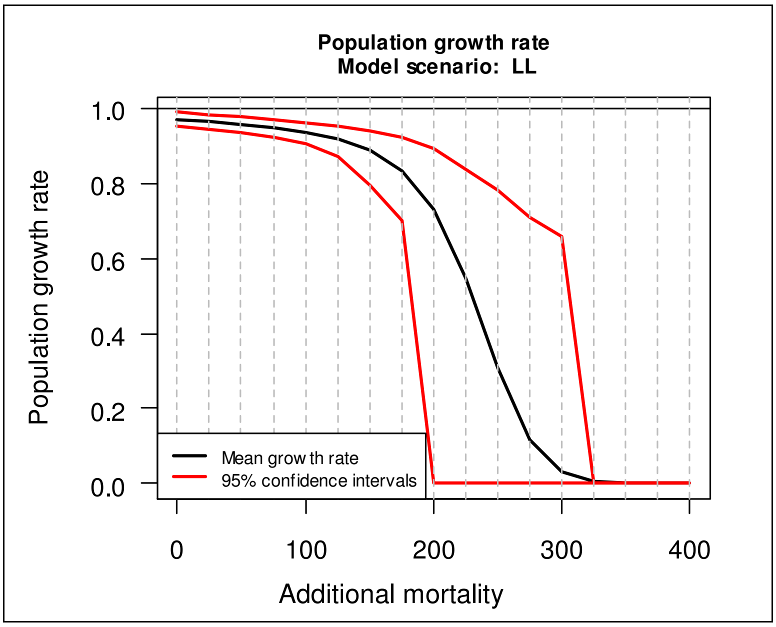
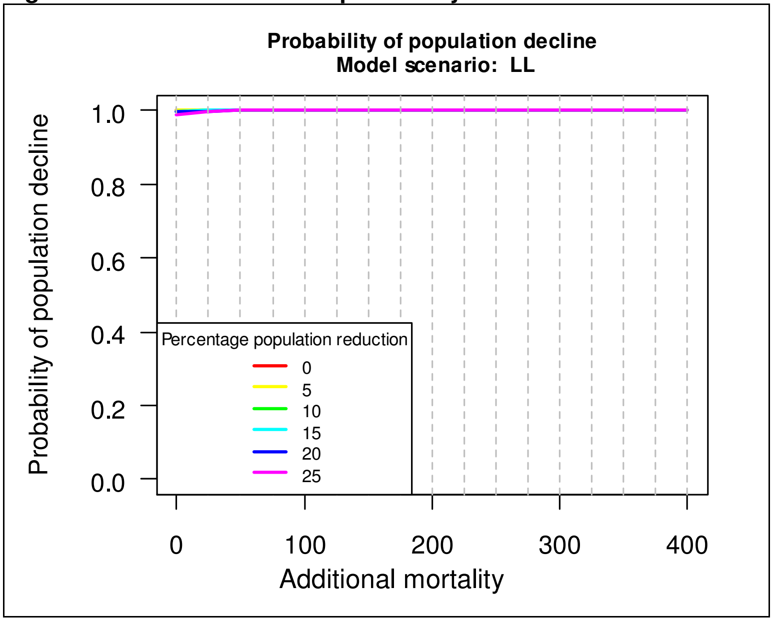


Figure 11: 'Historic' scenario probability of decline



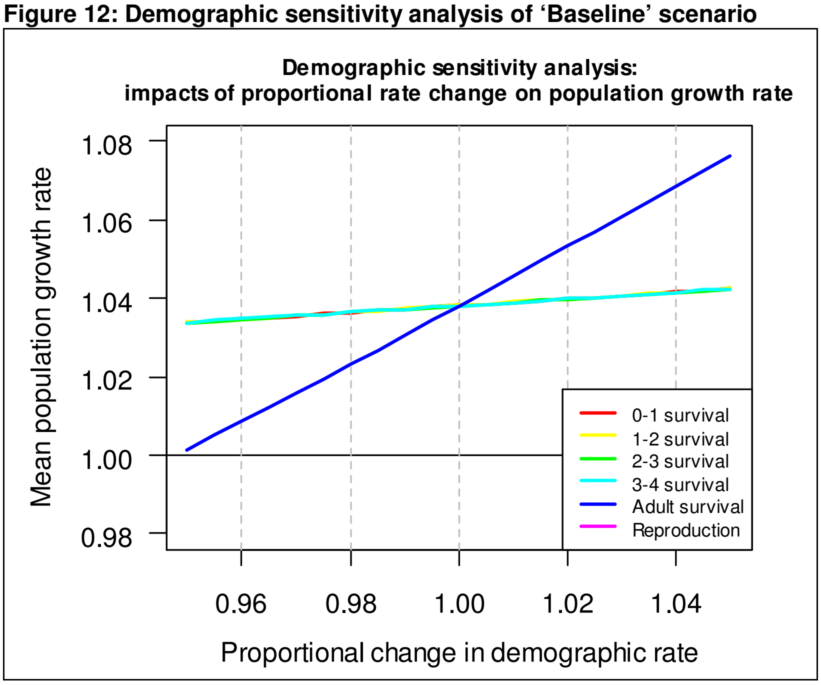
4 SENSITIVITY ANALYSIS

4.1.1 As requested by JNCC and Natural England, a sensitivity analysis was undertaken of the stochastic model and its predictions. Sensitivity analysis explores the relationships between the inputs and the outputs of the model and identifies the parameters which have the greatest influence on the results.

4.1.2 In this case, this was done by comparing changes in demographic rates (annual survival at different age classes, and productivity), against predicted mean population growth rates.

4.1.3 Figure 12 therefore presents a demographic sensitivity analysis generated using the 'Baseline' scenario and no additional mortality. Each demographic rate was perturbed in turn by +/-5% of its baseline value (at increments of 0.5%). This demonstrates that the demographic rate with greatest effect on population growth rate is adult survival, as would be expected for a comparatively long-lived and slow breeding seabird species. All other demographic rates generate virtually identical results, hence the lines are hidden underneath each other. The results from this analysis confirm that the worst case impact (elevated adult mortality) has been addressed using the population models.

Figure 12: Demographic sensitivity analysis of 'Baseline' scenario



5 DISCUSSION

5.1.1 The stochastic modelling has provided an alternative understanding of the lesser black-backed gull SPA population over the next 25 years and beyond. The Management scenario is considered to be as accurate a representation as possible of the likely conditions that would be required upon wind farm construction and operation under a process of adaptive management as advocated by Natural England. Nevertheless, population growth rates may well be underestimated under these conditions, since the model represents a precautionary 'closed' population without any assumed immigration into the SPA under improved conditions.

5.1.2 Input parameters have been selected that reflect a more stable colony than in recent times, based on records from Havergate Island in 2011, and backed up by information from other colonies across the UK and Europe. Although no site-specific information on adult survival was available, the value used was still considered to be realistic based on results from other comparable coastal colonies (e.g. Brown et al. 2004[5]; Camphuysen, 2011[6]).

5.1.3 The model shows that with targeted SPA management the downward trend for the SPA will reverse, and population growth will occur at a rate of around 7.4% (Figure 3), increasing to approximately 8,000 pairs over a 25 year period (Figure 2).

5.1.4 There is already some evidence of an upturn in fortunes, or at least a stabilisation of SPA numbers due to indirect SPA improvements, as witnessed from 2012 survey results (the equivalent of the 'Baseline' scenario). This year the total SPA population was estimated to be 1,811 pairs (640 at Orfordness and 1,171 at Havergate Island), which is an increase on 2011 (550 and 1,030 pairs) and 2010 (550 and 1,053 pairs).

5.1.5 Although many of the improvements to date have not been targeted specifically at the breeding lesser black-backed gull interest feature of the Alde-Ore Estuary SPA, there is reason to believe that this population has directly or indirectly benefitted, for the reasons outlined below. This shows that further targeted management would likely have even greater effectiveness in reversing the population's fortunes, in line with Natural England's expectations.

- RSPB indicate that the National Trust (owner of Orfordness) undertook limited improvements on habitat in proximity of the gull colony in 2011, that will potentially benefit breeding gulls.

[5] Brown, JG, Perrins, CM, Boyle, D, Duffield, S, Dustan, A, Easton, J, Smith, S. and Parsons, M (2004). Seabird monitoring on Skomer Island in 1999-2002. JNCC Report No.339

[6] Camphusen, C.J. (2011). Lesser Black-backed Gulls Nesting at Texel: Foraging, distribution, diet, survival, recruitment and breeding biology of birds carrying advanced GPS loggers. NIOZ Report 2011-05.

- Predator levels (primarily fox) will be lower due to LIFE+ habitat improvements within Orfordness – long-term changes to physical infrastructure and water levels at Airfield and King's Marshes will make much of the area less suitable for foraging with increased physical barriers to movement close to, and on the landward side of colonies at Lantern Marsh and the area from the Cobra Mist building to The Crouch. In occasionally flooded areas in Germany in the 1990s, fox density was 0.3-0.46 families/km^2 while on one regularly flooded site it was much lower (0.1-0.15 families/km^2) (Bellebaum, 2002 in Stillman et al. 2006[7]), suggesting that increased water levels will reduce habitat suitability.

- Predator control was undertaken at Orfordness early in the 2011 breeding season and numbers may continue to be suppressed due to a combination of this and changes in habitat. Fox predation is much lower on Havergate Island, and this is likely to be the main reason why many gulls moved from the previously large colony on Orfordness. At Havergate Island, a programme of rat eradication has also likely benefitted lesser black-backed gull chicks to some degree, as well as water level management and a change in management strategy by RSPB to stop the prevention of gull nesting in order to aid Annex I wader species.

- Improved coastal marsh and shingle habitat management across the estuary will reduce the likelihood of flooding incidents causing breeding failure, as well as potentially creating alternative nesting habitat.

- Greater management of human access and activities as part of the LIFE+ scheme will reduce disturbance events for breeding gulls.

[7] Stillman, R. A. MacDonald, M. A. Bolton, M. R., le V. dit Durell, S. E. A., Caldow, R. W. G, and West, A. D. (2006). Management of wet grassland habitat to reduce the impact of predation on breeding waders: Phase 1 Final Report. Centre for Ecology and Hydrology Dorset.

5.1.6 These improvements at Havergate Island and Orfordness are likely to increase both productivity, and crucially (as shown in the sensitivity analysis) adult survival values in the long-term. Adult survival rates are expected to improve because it has been shown that foxes have not just taken eggs and chicks, but there have also been periodic outbreaks of adult killings. Management improvements are also likely to improve food availability for adult gulls, whether it be increased invertebrate abundance in wet areas or increased numbers of waders and other breeding bird species.

5.1.7 Although growth is predicted under the Management scenario, it is clear that this will be insufficient to return the population to favourable condition (approximately 14,000 pairs) within a reasonable timeframe, regardless of whether any additional mortality will occur. The SPA population is expected to reach around 8,000 pairs over 25 years (around 6,700 pairs in the deterministic model), and average population growth is positive for all additional mortality rates tested (up to 400 birds), even at the lower 95% confidence limit (Figure 3).

5.1.8 Input parameters are realistic: good, but not the highest productivity levels recorded at Havergate Island in 2011, and adult survival rates recorded at the Texel colony in the Netherlands, despite signals of poor reproductive success caused by lower rates of provisioning than required (Camphuysen, 2011), and evidence of higher productivity elsewhere in the country (Gyimesi et al, 2011[8]). Nevertheless, under this 'closed' population scenario the population is still not predicted to return to favourable condition in a reasonable timeframe (likely to be over 30 years).

5.1.9 The assumption that the population is closed results, therefore, in model predictions that, in all cases, do not lead to the attainment of favourable condition in reasonable timeframes. A return of the breeding population to approximately 14,000 pairs will only be achieved if there is immigration.

5.1.10 Evidence suggests that immigration on a scale previously witnessed within the Alde-Ore Estuary SPA in the 1990s is unlikely, although, as understood by Natural England, it may still occur in future years. To encourage birds to a site, it must be relatively better quality than the one that birds leave. This may be due to a combination of factors such as habitat quality, breeding density, predation levels, food supply etc. Historically, birds left the SPA, in particular the large Orfordness colony, and moved to either Havergate Island, urban rooftops across Suffolk, or to the large Dutch colonies, to escape the increased predation threat (Piotrowski, 2012[9]). There is little scientific evidence to suggest that urban birds will return to coastal sites. However, in time, some individuals may move from other coastal sites, either across Suffolk, or from the continent. The lesser black-backed gull population in Holland has increased

8 Gyimesi, A., Boudewijn, T.J., Poot, M.J.M. and Buijs, R.-J. (2011). Habitat use, feeding ecology and reproductive success of lesser black-backed gulls breeding in Lake Volkerak. Bureau Waardenburg bv.

9 Piotrowski, S. (2012). Lesser Black-backed Gull and Herring Gull Breeding Colonies in Suffolk and South Norfolk. Unpublished report for RPS.

significantly since 1990, at a rate of 11% annually between 1990 and 2005. It then appeared to stabilise for a few seasons: however, in 2010 it passed 100,000 pairs, and in 2011 went substantially beyond that (upper range estimate 117,000 pairs). It is now the most abundant breeding gull in Holland.

5.1.11 It is acknowledged that to date, the UK breeding population has comprised solely of the *Larus fuscus graellsii* race and that mainly the *L. f. intermedius* race breeds in the Netherlands and Belgium. However, this not need necessarily be the case in the future, when different pressures on population dynamics will be in place. Ringing recoveries have shown that birds from Orfordness have moved to natural sites in The Netherlands with many in the Rotterdam area and several in the Zeeland region. One was reported as probably breeding on the island of Schiermonnikoog in 2001. In Belgium, several are breeding around Zeebrugge and in France two Orfordness-reared birds are at Le Clipon (nr Dunkerque) and another at Calais (Piotrowski, 2012). Although data on mixed breeding are scarce, recent studies have shown there is unrestricted gene flow between races (OSPAR, 2009[10]). Analyses of the phylogeography of lesser black-backed gulls (Liebers and Helbig, 2002[11]; Crotchet, 2002[12]), suggests that there is little evidence for separating races, both phenotypically and genetically. It is therefore a possibility that in future years, a mixing of races may occur in colonies in southeast England if conditions are advantageous for doing so.

5.1.12 It is considered that 50% of all Dutch lesser black-backed gulls breed in the Waddensea area, which based on results of recent GPS-tracking data of birds from the Texel colony[13], are within at least occasional foraging range of the Alde-Ore Estuary SPA, and individuals have been recorded on occasion visiting the SPA during the breeding season over a number of years. A further 42% breed in the Delta (the southwest of the Netherlands), and this is also within mean maximum foraging range (141km, Thaxter et al. 2012[14])

5.1.13 Several of the big colonies in that region are currently showing poor breeding success, with young chick predation by other lesser black-backed gulls particularly high at some places, and fox predation at others. It is considered that if the current levels of failure continue, the populations at coastal sites are expected to collapse. Many birds are likely to continue the recent trend of moving to urban sites, and others may move to other more isolated coastal sites where fox predation will be lower. In these circumstances it is possible that a combination of increased nesting density, predation and food competition

[10] OSPAR Commission (2009). Background document for Lesser black backed gull Larus fuscus fuscus. Biodiversity Series. http://qsr2010.ospar.org/media/assessments/Species/P00409_lesser_black_backed_gull.pdf

[11] Liebers, D. and Helbig, A.J. (2002). Phylogeography and colonization history of Lesser Black-backed Gulls (Larus fuscus) as revealed by mtDNA sequences. Journal of Evolutionary Biology 15 (6), 1021– 1033.

[12] Crochet, P-A., Lebreton, J-D. and Bonhomme, F. (2002). Systematics of large white-headed gulls: patterns of mitochondrial DNA variation in western European taxa. The Auk 119(3): 603–620.

[13] http://www.uva-bits.nl/project/multi-scale-movements-of-gulls-from-texel/

[14] Thaxter, C.B., et al. (2012). Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. Biol. Conserv., doi:10.1016/j.biocon.2011.12.009

may force birds to move further afield. With improved management, the Alde-Ore Estuary SPA may become a colony of net immigration in future years, if the habitat is again seen as relatively high quality. There is an apparent precedent for this behaviour - the island of Forteiland at Ijmuiden, the Netherlands, was fox-free in the 1980's and up to 1988 the colony increased. In the breeding season of 1988 however, one fox reached this island, and this coincided with the abandonment of the island for 15 years. This absence lasted until 2003 when the island was reoccupied. In 2007, the number of breeding pairs approximately reached numbers in 1988[15].

5.1.14 It is therefore unlikely that in future years the population will in practice be 'closed'. Whilst immigration may not occur on a scale previously seen at the Alde-Ore Estuary SPA, under the Management scenario and coupled with population trends and pressures seen within some of the large Dutch colonies, the SPA may well attract birds from abroad (as well as from other colonies across Suffolk) due to the better nesting conditions provided. This would result in greater growth rates than predicted (with higher overall survival and productivity), and whilst still considered unlikely, there is potential that Natural England's population target could be met, but only if targeted, long-term, additional SPA management is implemented (i.e. under the Management scenario).

6 CONCLUSIONS

6.1.1 This note summarises the results of further PVA modelling that takes account of stochastic variability in key demographic parameters. Overall the stochastic model has generally provided comparable indications of population growth to the deterministic model. The likely fate of the lesser black-backed gull population of the Alde-Ore Estuary SPA is predicted based on a reasonable assumption about reproductive success and survival as a consequence of targeted SPA management changes. Alternative scenarios which assume alternative values for these parameters have also been modelled. In addition the effect of additional mortality on the fate of the population has been considered for each scenario.

6.1.2 The approach to modelling has been informed and refined through consultation with JNCC, Natural England and the RSPB.

6.1.3 The Management scenario model predicts that with targeted SPA management, a positive growth rate will still be maintained within the population even if there are 400 additional deaths. In the alternative scenarios considered, with less targeted or absent management, this threshold is accordingly lower.

6.1.4 Confidence in these predictions has been built into the model, with a 95% confidence interval showing a levelling of population growth at around 400 additional deaths (Figure 3). The deterministic model also predicts similar

[15] http://www.gull-research.org/ijmuiden/index.html

results, with positive growth until 370 individuals are lost. Adult survival is the most sensitive parameter to the model, and although it is acknowledged that no site-specific data are available, the value used is representative of favourable conditions within typical coastal colonies.

6.1.5 Based on recent consultations on favourable condition for the breeding lesser black-backed gull population of the Alde-Ore Estuary SPA, it is Natural England's opinion that "*more effective management of certain local factors such as mammalian predators, human disturbance and vegetation growth may facilitate population recovery*" [email Sam Stewart, 30.05.12]. However, from the output of the 'closed' population modelling it is confidently predicted that, even in the absence of any additional mortality, there is no prospect of achieving a favourable condition for this population within a reasonable timeframe, irrespective of the scenario considered. It is clear that the only circumstances in which favourable condition for this interested feature at this site will be reached in a reasonable timeframe is through immigration of birds from other breeding sites, as a consequence of targeted, long-term additional management of the SPA.

6.1.6 The modelling has assumed that there will be no immigration in to the breeding population, which may occur if conditions are relatively favourable compared to other colonies (under the Management scenario with targeted SPA improvements). This may be considered a <u>precautionary</u> assumption given that there is evidence to suggest the mobility of this species and its tendency to colonise and expand within new breeding locations. Any immigration would create additional growth in the population and this would lead to a higher absolute rate of additional mortality that might be considered to be sustainable.

APPENDIX 1: LESSER BLACK-BACKED GULL PVA MODELLING APPROACH

1.1 In response to the consultation note from JNCC (14 October 2011) and the outcomes of the teleconference meeting with GWFL, JNCC and Natural England on 20 December 2011, this technical summary aims to address issues raised and provide information and rationale behind the methods and parameters used for the Population Viability Analysis (PVA) undertaken for the effects of additional mortality on the Alde-Ore Estuary SPA lesser black-backed gull population, as presented in the Habitat Regulations Assessment (HRA) report. It also provides comparative information on the parameters and methods that would be required to produce a stochastic PVA model.

Demographic Rates used

1.2 In general, compared to some other seabird species, there are relatively few comprehensive studies of lesser black-backed gull population dynamics. A review by Maclean et al. (2007) summarised the data sources available for use in PVA modelling for this species, and these were considered for the demographic PVA model where relevant. Other more recent publications have also been used, including those by Mavor et al. (2008) and Camphuysen (2011). The 'Baseline', 'Historic' and 'Management' scenario parameters used in this model and rationale for selection are detailed in Appendix 2.

1.3 Any stochastic model produced (as requested by JNCC) would have to be bespoke for this population, and follow best practice methods (e.g. selection of appropriate probability distributions for survival and reproduction). A stochastic model for the lesser black-backed gull population would be based on the same demographic data used in the deterministic model, with the addition of estimates of the variance on these rates. (see below and Appendix 2, Table 1). The modelling would also be informed by the lesser black-backed gull model presented by Poot et al. (2011), although certain methodological aspects of their approach are not considered appropriate for the present purposes.

Deterministic model and parameter uncertainty

1.4 The recent report for the Dutch offshore wind farm at Egmond an Zee by Poot et al. (2011) provides results of the application of a stochastic population model to a range of seabird species present in the North Sea, including lesser black-backed gull. The demographic rates used were derived from the same primary source (Wanless et al 1996, who recorded population dynamics within the Isle of May, Scotland) as used in the RPS model. We considered these data to be of low suitability for producing a stochastic model, since only 4 years of adult survival rates were presented, from which the mean was taken (Table 2 in Appendix 2), immature survival was estimated indirectly and productivity was based on only six years of data. In addition, Poot et al. (2011) have incorrectly used the standard errors (SE) provided by Wanless et al. (1996) as standard deviations (SD), which they have used to generate random demographic rates. This appears to be an error, as the reported SEs in Wanless et al. (1996) are actually measures of the reliability of the mean estimate, not a measure of the expected temporal variation in the survival rates. Thus the stochastic model presented does not simulate the range of expected survival rates but rather the estimated probability distribution within which the 'true' mean survival rate, based on the estimated value, is predicted to lie. This will lead to underestimation of temporal variation in the gull population.

1.5 The deterministic modelling presented by RPS encompassed the range of survival rates from Wanless et al. (1996), as well as other sources, in the three scenarios described in the Environmental Statement and HRA report. We consider this to be a more realistic and transparent approach to modelling in the presence of such limited information on rate variability. While stochastic predictions generated using poor estimates of variability will provide an impression that uncertainty has been accounted for, this may in fact provide a misleading impression of model robustness, through the implicit assumption that stochastic simulations encompass the full range of possible outcomes. However, this will only be the case if the rate variabilities used are a fair reflection of the true range of variability in the wild populations. Due to the lack of data on variability in survival rates, stochastic outputs would be based on a very short span of years from a single colony and therefore are unlikely to be representative. This would lend an unwarranted sense of robustness to the approach. The scale of effects predicted by the collision scenarios are also expected to be similar to those obtained using the suite of deterministic models described above (albeit measured as the percentage change in the probability of a given outcome rather then the percentage change in the population growth rate), and thus the benefit is considered to be minimal at best.

1.6 The table in Appendix 2 includes preliminary estimates of demographic rate variance for a stochastic model.

Outputs

1.7 We note JNCC's comment:

We consider the most informative output from population modelling to be probabilistic in nature (this again precludes the use of a deterministic model). Probabilistic outputs enable an assessment of the likelihood of to a population experiencing user-defined changes (e.g. a 5% decline) in the presence of a range of additional mortality and allow an assessment of the increase in risk posed by this mortality.

1.8 As discussed above, we consider that the apparent benefits described in this comment are based on a presumption of reliable estimates of mean demographic rates and their variances. We agree that given reasonable spans of years, the above statement is correct. However, more limited datasets make this approach more problematic and reduces the quality of risk-based advice based on such modelling. It is for these reasons that we consider a stochastic model for this population will add little of value to the current assessment.

1.9 Outputs from any stochastic model would be expressed as probabilities of a given outcome from the simulations, such as the proportion of model runs which result in a population decline of 50% within the simulated period. Sensitivity analysis (including proportional sensitivities: ‘elasticities’) would be conducted to identify the demographic rates (and variances) to which the population growth rate is most sensitive. This is achieved by systematically changing each demographic rate (or variance) in turn across a range of values (either absolute for sensitivity analysis or proportional for elasticity analysis) and estimating the average population growth rate obtained across multiple simulations. Plotting the growth rate against the magnitude of change in each demographic rate enables determination of the relative contribution each rate makes to the population growth rate.

1.10 The issue of assessing an impact of the additional mortality on the likely attainment of favourable condition is one that will be conducted through further correspondence with JNCC and Natural England. Whilst the SPA population has declined significantly since its citation, it is considered unrealistic that a recovery could be made to such previous peaks at the citation date, regardless of levels of additional mortality or indeed management improvements. Agreement will therefore be sought with all parties on a realistic population target.

Modelling mortality

Mortality range

1.11 A range of mortality has been modelled in the deterministic PVA, based on results from the collision risk modelling calculations achieved from various avoidance rates considered. Whilst this provides a good indication of what this realistic range may have on population dynamics, further interpretation of the risks can be made based on a suitably selected range of “additional mortality” (harvest rate) and independent of collision risk modelling output, as requested by JNCC/Natural England.

Additional mortality modelled as proportional to the population size.

1.12 This will be accommodated in any revised model outputs (i.e. calculate the proportion of the current population current size estimated to be killed due to collisions to generate an estimate of the proportion of the population likely to be killed each year, based on the current levels). This was omitted in the original models since the low rate of population growth predicted for this population means that proportional mortality would not differ markedly from absolute mortality.

Effect of sub-adult mortality on recruitment within the population

1.13 In the current deterministic model outputs all additional mortality is applied to the breeding adult age class. Refinements to the estimates of annual mortality on the breeding population in the submission documents have already accounted for a proportion of sub-adults recorded within the GWF site during monthly boat-based surveys. This resulted in a reduction of estimated mortality by approximately 7%. Although this would mean that mortality effects may therefore be underestimated for the population as a whole, in reality differences in predicted effects on the population are likely to be very small. Evidence (e.g. Camphuysen, 2011) suggests that the composition of birds foraging within the GWF site is likely to consist of more non-breeding birds from other colonies than predicted in the report. This will at least partly balance the effect of discounting sub-adults from the Alde-Ore Estuary SPA population in the PVA. Any revised PVA modelling would however consider mortality on all age classes.

Temporal period of mortality risk

1.14 Although numbers recorded in February during GWF surveys were generally higher than previous winter months and comparable with early breeding season levels, as Stone et al. (1995) reported, lesser black-backed gull numbers increased in the southern North Sea from February onwards, due to birds returning north to breeding colonies. A large proportion of birds recorded within the GWF in this month are therefore likely to be migrants from colonies further north across northwest Europe.

1.15 Even though Wetland Bird Surveys, tagging studies and ringing recoveries show that a small number of SPA birds may still be found within the GWF site at some point during winter months, SPA mortality rates are likely to be balanced by the inclusion of March and August in collision risk modelling calculations, when many birds recorded are likely to be on migration to and from other breeding colonies, and therefore not part of the SPA population. As such, consideration of additional mortality rates on the SPA population in the PVA can reasonably be limited to the six summer months, rather than using annual mortality figures.

APPENDIX 2: PVA INPUT PARAMETERS

Table 1: Input parameters used for PVA and rationale behind this usage. Standard Deviation (SD) for use in a stochastic model is also shown.

Parameter	Scenario	Value used (SD)	Rationale
Juvenile survival rate	All	0.45 (0.2)	Wanless *et al.* (1996) found that fitting their model to the data obtained for the lesser black-backed gull produced unrealistic estimates, with adult survival greater than one and negative values for survival to breeding age. For the purposes of this model, a four year compound survival rate is taken from the herring gull juvenile survival in Wanless *et al.* (1996). Raising this to the power 4 gives a survival rate for each of the first four annual transitions of 0.82 (SD 0.03). The estimated survival rate of fledged herring gull young to breeding age of 4 years which return to breed on the Isle of May was 0.45 (SE = 0.07). No other estimates for lesser black-backed gull juvenile were available in the literature. Within the Alde-Ore Estuary SPA, herring gull numbers have appeared to follow the same downward trend as lesser black-backed gull, and therefore juveniles have likely been subjected to the same influences on survival rates.
Age of first breeding	All	4 years	Taken from Wanless *et al.* (1996) when relating to juvenile survival of herring gulls (see above), although this corresponds with the accepted value for lesser black-backed gulls in BTO's BirdFacts (http://blx1.bto.org/birdfacts/results/bob5910.htm) and BWPi
Adult survival rate	Historic	0.90 (0.025)	based on recommendations by Maclean *et al.* (2009) and Garthe and Hüppop (2004). In both of these reports, species that have very high survival rates (i.e. including lesser black-backed gull) are likely to have rates >0.90. This lowest value was selected as it was reported that adult mortality within the Alde-Ore Estuary SPA in the recent past may be occasionally increased due to predation by red foxes. There is no evidence of recent food shortages which would significantly reduce adult survival to low levels seen elsewhere (e.g. Skomer, Brown *et al.* 2004) when the sudden removal of a food sources (fishery discards) occurred. Standard deviation derived from the four annual estimates in Wanless et al. (1996; Table 2). This was also used in the medium and high models. In Wanless *et al.* (1996), estimated mean annual survival rates for females and males over a four year period (without culling of adults) were 90.7% (SE = 1-8) and 91 8% (SE = 1 6%), respectively (Table 2). Annual variation in survival was not statistically significant. Assuming no sex differences, the estimated mean survival rate for lesser black- backed gulls was 91.3% (SE = 1-2%). The estimated mean annual survival rate of lesser black-backed gulls on Skomer, 1978-2000 was 0.89 (Brown *et al.* 2004). This may be conservative as in the face of continued failure to breed due to food shortages, it was possible that a proportion of the population emigrated (Brown *et al.* 2004).
	Baseline	0.93 (0.025)	Recommended by Garthe and Hüppop (2004) for lesser black-backed gull and derived from Wanless *et al.* (1996). This also

Parameter	Scenario	Value used (SD)	Rationale
			equates to a medium value between the two recorded estimates of survival rate used for Historic and Management scenarios. In two of the four years recorded by Wanless *et al.* (1996), mean annual survival rates exceeded 0.93 (Table 1). Over the period of 1978 to 2000 at Skomer, adult survival approached or exceeded 0.93 in six years, despite food shortages and low productivity rates (Brown *et al.* 2004).
	Management	0.95 (0.025)	Taken from recent coastal colony count data in Texel, The Netherlands, where despite signals of poor reproductive success caused by lower rates of provisioning than required, adult survival rates were high (Camphuysen *et al.* 2011). Here, between 2006 and 2010, 180 breeding adults were colour ringed (82 males, 98 females). Return rates suggested that the annual survival in both sexes must have been over 0.95, under the assumption that all surviving birds returned to the colony and that ring-losses did not occur (rates would therefore be higher in case of ring losses and/or emigration). This is a reasonable assumption as recoveries of gulls ringed on the Isle of May show that once birds have bred they seldom, if ever, change colonies (Chabrzyk and Coulson 1976; Coulson 1991). Over the period of 1978 to 2000 at Skomer, adult survival approached or exceeded 0.95 in five years, despite food shortages and low productivity rates (Brown *et al.* 2004).
Proportion of breeding adults in population	All	0.66	The proportion of adults which breed was taken from Calladine and Harris (1996). Over two years, 34% and 40% marked adult lesser black-backed gulls seen on the Isle of May did not breed (no culling was undertaken). Breeding adults usually represent less than 50% of the total number of birds present within a typical seabird population (Reeves and Furness 2002), and a literature review in Calladine and Harris (1996) showed that the proportion of non-breeders in similar species' populations (gulls, skuas) is likely to be at least two thirds. A 30% level of 'floaters' was used in modelling by Poot *et al.* (2011).
Reproductive rate	Historic	0.45 (0.23) chicks per pair	This level is seen as a reasonable average of long-term productivity rates within the SPA of years that have shown complete failure, and years where SPA colonies have shown some success. Across the Havergate Island colonies in 2011, average productivity of lesser black-backed gulls was 0.50 young per nest (Alde-Ore Future for Wildlife, 2011[16]). Wanless *et al.* (1996) showed that productivity varied greatly between years on the Isle of May, indicative of the varying control measures used (culling). In relatively undisturbed areas, productivity varied from 0.54 to 1.04 young reared per nest. Standard

[16] http://www.lifealdeore.org

Parameter	Scenario	Value used (SD)	Rationale
			deviation was estimated from the six annual estimates provided in Wanless et al. (1996). This was also used in the medium and high models. An average productivity of 0.46 chicks per pair over four years was recorded at the Texel coastal colony in the Netherlands by Camphuysen (2011). These results were considered to be low due to the impact of cannibalism which most likely occurred due to food availability stress. (the standard deviation from this study was 0.17, which is similar to the 0.23 from Wanless et al. 1996). The UK trend of lesser black-backed gull productivity produced by JNCC (2011)[17] is heavily influenced by data from one very large colony on Skomer, SW Wales. Here, productivity has fluctuated widely, though has often been low, for unknown reasons. The average productivity level over the long-term was likely to be around 0.40-0.50 chicks fledged per pair. Mavor *et al.* (2006) reported that breeding success data at 11 colonies in southwest Scotland where mink predation was uncontrolled, the fledging rates were c.0.50 (from 598 pairs) chicks per pair.
	Baseline	0.80 (0.23) chicks per pair	In 2011 on Havergate Island, the gull colony along the shingle bank produced 1.58 young per nest, and the Doveys lagoon powerhouse colony produced 0.86 young per nest. The salt-marsh colonies produced on average for both species 0.41 young per nest, and so 0.80 is a reasonable value to represent an average colony. The most recent productivity rate for the Texel colony was 0.71 chicks per pair in 2010, which continued to be a stressed population (Camphuysen, 2011). Average productivity presented by JNCC across recorded UK colonies reached up to 0.80 on occasion, despite being heavily influenced by the relatively unsuccessful Skomer colony. No data were available for other individual colonies. Although food shortages have been thought to be the cause of this very low nesting success on Skomer for many years, very poor weather may contribute to low success in a particular year (Brown *et al.* 2004). Breeding success data at 13 colonies in southwest Scotland (Mavor *et al.* 2006), indicated that at two colonies where mink were controlled, lesser black-backed gull fledged 50% more chicks than at sites with no (or unsuccessful) mink control; the fledging rates at these two sites were c.0.75 (from 108 pairs). Productivity in 2006 on the Isle of May from a sample of 333 nests was 0.88 chicks per pair, considered an average figure for the

[17] http://jncc.defra.gov.uk/page-2886

Parameter	Scenario	Value used (SD)	Rationale
			colony (Mavor *et al*. 2008). Duncan (1981) estimated productivity at 0.85 young per pair for the colony. At North Hill, Orkney, the mean for 2005-06 was 0.80 chicks fledged per pair (Mavor *et al*. 2008).
	Management	1.0 (0.23) chicks per pair	Results from the shingle colony within Havergate Island showed a productivity of 1.58 young per nest. This colony is likely to have benefitted from site management improvements already underway (rat eradication and habitat improvements). Gyemisi *et al*. (2011) recorded an average of 1.62 young per pair in a control area at Lake Volkerak, the Netherlands. In this area, predation rates may have been lower than the surrounding colony parts, resulting in this relatively high rate. As an inland colony, food resources may also have been more reliable. At the Isle of May, productivity was recorded 1.4 fledged young per pair in 2005 (Mavor *et al*. 2008), with fox predation presumably being absent.
Sex ratio	All	50:50	The sex ratio of both collision victims and fledged chicks is assumed to be 50:50. This follows Wanless *et al.* (1996) who did not differentiate between significant annual survival between sexes, and assumed an equal ratio for fledging.
Migration	All	Closed population	In the absence of data on rates of immigration and emigration between the SPA population and others in the region the model assumes a closed population. This was also assumed by Wanless et al. (1996). In most instances this assumption has little impact on the results obtained (as exchange rates are often low and/or balanced). In addition this is precautionary, since the population is unlikely to act as a source for new birds (given that the population appears to be well below carrying capacity and that productivity has been low in some previous years) and if the population is supported by net immigration this would reduce the observed population impact relative to that modelled, i.e. the modelling is conservative since it does not include any mechanism by which it can increase, aside from reproduction. Although a distinction between mortality and emigration could not be made by Brown *et al.* (2004), in the face of continued failure to breed due to food shortages, it remains possible that a proportion of the Skomer population emigrated. The decline of the lesser black-backed gull population on Skomer during the mid 1990s was attributed largely to a reduction in fishery discard feeding opportunities (Sutcliffe 1997). However, the productivity estimated by Brown *et al.* (2004) has been consistently far too low to sustain the population (let alone provide for its recent increase) without immigration. In an improving situation such as that within the Alde-Ore Estuary SPA, it is likely that immigration would outweigh emigration rates.
Density dependence	All	Density independence	It was agreed in the teleconference meeting with JNCC and Natural England on the 20 December 2011 that in the absence of robust justification the modelling should remain density independent. Of note here is that the Poot et al (2011) model includes a ceiling density dependence on reproduction which was set at the highest known population size. Consequently the modelled populations are all constrained around this size. There is no evidence to suggest that such restrictive population control is

Parameter	Scenario	Value used (SD)	Rationale
			realistic, and the choice of level at which to set density dependence controls the predictions obtained. This is a clear illustration of how decisions regarding the strength of density dependence can dictate the results obtained. While density independent simulations are also based on an unrealistic premise (that of potentially unlimited growth), this is a more reasonable assumption within typical prediction time frames than simply assuming that population regulation is present and so must be included, even if this requires fabrication of the mechanism and strength to satisfy this assumption. The model run by Wanless et al. (1996) assumes that population growth is unlimited and that there is no density dependence, conditions which apply when the population is well below its carrying capacity, as is considered to be the case within the Alde-Ore Estuary SPA.

	Estimated annual survival (SE) Herring gull			Lesser black-backed gull		
Year	Male	Female	Total	Male	Female	Total
1989	87·2(4·0)	96·7(2·7)	91·9(2·4)	90·2(4·3)	97·6(3·0)	93·7(2·7)
1990	93·4(3·5)	84·7(4·3)	89·1(2·9)	89·4(3·7)	90·9(3·8)	90·2(2·6)
1991	82·5(5·2)	90·0(3·9)	86·1(3·3)	96·2(2·9)	90·8(3·7)	93·4(2·4)
1992	79·2(5·1)	88·8(3·7)	84·2(3·2)	90·9(3·5)	86·0(4·2)	88·6(2·8)
Mean*	85·8(2·0)	89·8(1·6)	88·0(1·3)	91·8(1·6)	90·7(1·8)	91·3(1·2)

Table 2. Estimated annual survival rates allowing time-dependent recapture rates. * estimated assuming constant survival. From Wanless *et al.* (1996).

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