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MacArthur Green Ltd

Client: The Crown Estate SOSS

Project: SOSS-04 Gannet Population Viability Analysis

Date: May 2012

Report: Developing guidelines on the use of Population Viability Analysis for investigating bird impacts due to offshore wind farms

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The SOSS steering group includes representatives of regulators, advisory bodies, NGOs and offshore wind developers (or their consultants). All SOSS reports have had contributions from various members of the steering group. However the report is not officially endorsed by any of these organisations and does not constitute guidance from statutory bodies. The following organisations are represented in the SOSS steering group:

SOSS Secretariat Partners:	The Crown Estate
	British Trust for Ornithology
	Bureau Waardenburg
	Centre for Research into Ecological and Environmental Modelling, University of St. Andrews
Regulators:	Marine Management Organisation
	Marine Scotland
Statutory advisory bodies:	Joint Nature Conservation Committee
	Countryside Council for Wales
	Natural England
	Northern Ireland Environment Agency
	Scottish Natural Heritage
Other advisors:	Royal Society for the Protection of Birds
Offshore wind developers:	Centrica (nominated consultant RES)
	Dong Energy
	Eon (nominated consultant Natural Power)
	EdF Energy Renewables
	Eneco (nominated consultant PMSS)
	Forewind
	Mainstream Renewable Power (nominated consultant Pelagica)
	RWE npower renewables (nominated consultant GoBe)
	Scottish Power Renewables
	SeaEnergy/MORL/Repsol (nominated consultant Natural Power)
	SSE Renewables (nominated consultant AMEC or ECON)
	Vattenfall
	Warwick Energy

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1. INTRODUCTION

1.1 Offshore wind farms have the potential to impact on seabird populations through elevated mortality and reduced productivity. The implications of these impacts for the seabird populations affected need to be understood in order that informed decisions can be made regarding the licensing of offshore wind farms. Population modelling can provide a framework within which such impacts can be explored.

1.2 The purpose of this document is to set out some of the key aspects which should be considered with regards to undertaking population modelling for the purpose of exploring offshore wind farm impacts. This is intended as 'high level' guidance, covering data requirements, the need for engagement with stakeholders (e.g. statutory nature conservation agencies, RPSB, JNCC), the model types which can be used and appropriate forms of output. Indeed, it is worth stressing the importance of planning and maintaining regular communication with stakeholders during model development and subsequent reporting to ensure the outputs are suitable for robust assessments to be made in the context of conservation objectives.

1.3 It should be noted that the use of PVA software (e.g. Vortex, RAMAS, etc.) is not considered here. Using off-the-shelf population modelling software can provide a useful starting point when investigating potential population impacts. However, these programmes are not always transparent in their internal mechanisms, and the requirements of any particular population modelling exercise are likely to be more appropriately addressed via bespoke modelling. This need not be complicated; simple models can be produced using spreadsheets such as Excel. More complicated ones (e.g. stochastic) can be developed within a commonly used programming language such as R or MatLab.

1.4 When presenting a population model, perhaps the most important requirement is a clear description of the assumptions which have been made, and how these may influence the model's outputs and their interpretation. At each step of the process, assumptions should therefore be described in the reporting, along with some discussion of why this has been made, and the potential consequences.

1.5 It is useful to bear in mind that population modelling is a useful tool, but can only be as reliable as the data on which it is based (hence: 'rubbish in – rubbish out'). It should also be stressed that the predictions generated by a model are best considered in a relative context (i.e. impacted vs. non-impacted), rather than treating the predictions as absolute. Thus reporting of outputs should focus on changes in measures of population status (e.g. population growth rate, probability of decline, etc.), not the predicted population size itself. The period over which projections are run (e.g. the span of years) should be chosen as a balance between the period of impact being considered (e.g. the lifetime of a wind farm) and the decrease in reliability of model outputs with increasing number of years.

2. PVA GUIDELINES

2.1 Below is a list of questions which should be considered prior to undertaking population modelling, and accompanying each is a discussion of the key points these raise.

2.2 Each point should be considered in project planning and subsequent discussions between the modeller and stakeholders as the project progresses.

Why is population modelling being considered?

- Can a 'population' be reliably determined for the impacts of concern?
- Over what spatial scale could the impacts be operating?

Which population to model?

2.3 Seabird populations are only fixed in size at the broadest spatial scale, which will probably be beyond the scope of most assessments. The exception to this will be for very small and/or localised populations, for example of rare species. Thus, it is necessary to consider the spatial and seasonal aspects which determine the size of the population under consideration. For example, if the population of concern is one associated with a breeding colony, then potential impacts are likely to be confined to the breeding season. Outside the breeding season the population 'at risk' is likely to be drawn from a much larger pool of individuals. If year round impacts, affecting both the 'local' breeding population and the 'wider' passage or wintering population are under consideration then it may be appropriate to undertake modelling at two or more scales, reflecting the seasonality of seabird movements and populations. Alternatively, a precautionary approach could be adopted, whereby all modelling is on the basis of the local 'breeding' population. This may overestimate the extent of impacts, so the implications of this need to be considered.

Exchange between populations

2.4 The degree of interchange between breeding colonies may also need attention, although in most cases there is unlikely to be any estimate of the extent of exchange. The assumption of a 'closed' population is typically necessary under such circumstances and the impact of this on subsequent predictions should be considered.

Are suitable demographic data available for the species/population?

- The quality and suitability of data will determine what form of population modelling is appropriate, e.g. deterministic/stochastic, density independent / dependent, level of age/stage structure and also the reliability of the outputs generated.
- A minimum of regular (ideally annual) population counts is required.
- Note, however, that just because detailed demographic data are available, it does not necessarily follow that a complex model is required to address the questions raised.

Deterministic or stochastic?

2.5 The term 'suitable demographic data' needs careful thought before further modelling work begins. Suitable in this context is relative to the questions being addressed. A very simple population model, lacking in stochastic variation and density dependence, can still provide guidance on the probable scale of an impact, under the assumption of constant conditions. Such a model generates predictions of average trends, which may be sufficient to determine the relative change to be expected for an impact of given magnitude. While such a model may appear to be an over-simplification, if little is known about how the population size has varied, or how the scale of impact may vary, it may represent a more honest assessment of the current understanding of the population and how it may be impacted.

2.6 In addition, the outputs from a simple model (i.e. deterministic) can often reveal that the relative effect of the impact in question is of such a small size that there is little requirement to undertake more complicated modelling. Thus construction of a simple model, based for example on average demographic rates, is often a valuable first step which may preclude the need for further work.

2.7 If probabilistic outputs are seen as being useful, and there are sufficiently robust data to support the development of a stochastic model then environmental and demographic stochasticity can be incorporated. This is typically achieved by the inclusion of randomly generated demographic rates into the model structure. Since each run of a stochastic model produces a different outcome it is necessary to run the model many times (e.g. 1,000s) in order to build up a probability distribution of outcomes. Technical aspects of how to produce a stochastic model are not within the remit of this guidance document, but should be sought from the literature (e.g. Morris and Doak 2002). Details of how rate variance has been modelled must be included. It is important that appropriate probability distributions are used for different demographic rates (e.g. ones bounded at zero and one for survival rates) in line with realistic natural constraints on those rates.

2.8 If the data permit, the total variance on average demographic rates can be partitioned into sampling and process variance. The latter is preferred for population modelling since it provides a more accurate reflection of the underlying temporal variation present in the study population. Sampling variance is an estimate of error associated with analysis methods (e.g. sample size). Methods to estimate process variance are established for certain types of survival analysis (for details see: http://www.phidot.org/software/mark/docs/book/), and their use in predictive modelling can considerably reduce the span of confidence intervals generated by a stochastic model. Partitioned variance estimates are not always available however, in which case model outputs will necessarily include both forms of variance. It is important to state in the model description which type of variance has been used (i.e. process variance or total variance).

Environmental and demographic stochasticity

2.9 The difference between environmental and demographic stochasticity can be thought of as follows: Environmental stochasticity describes the incorporation of randomly generated values for the *probability* of survival from one time step to the next. Demographic stochasticity is the process by which random *numbers* of surviving individuals are generated for any given survival probability. Thus environmental stochasticity models variable environments (e.g. weather effects) while demographic stochasticity models chance effects due to the population size. Demographic effects can usually be ignored for populations of more than 100 individuals. Therefore, if simulated populations may decline to around this level it is worth including to ensure that chance effects are included in the outputs. However, there is no penalty to including demographic stochasticity when simulating larger populations.

Density dependence

2.10 While the presence of density dependent population regulation in wild populations is often assumed, direct evidence is rare. Thus, although it may appear that a model which lacks density dependence is inherently wrong, it is arguable if this is indeed any more wrong than incorporating density dependence in the absence of evidence for its presence or mechanism. Since the influence of density dependence on a population model's outputs can be dramatic, this aspect needs careful consideration.

2.11 It is also worth noting that the inclusion of density dependence in a population model is often regarded as a precautionary step. This is based on the premise that regulation will limit population growth, with the implicit assumption being that the modelled population is therefore more vulnerable to impacts. However, this need not be the case in all circumstances. Density dependence may limit population size, but its effect on population growth is obviously determined by the population's size. Thus, if a population is reduced in size by an impact, density dependent regulation will be relaxed and this will trigger an increased in the growth rate. In this manner a density dependent population is 'buffered' against declines as well as constrained from unlimited expansion. A density independent model lacks this ability to recover when reduced to a small size (e.g. through increases in reproduction or survival). Hence a density independent model formulation is often more precautionary when considering potential negative impacts on a population.

2.12 Clearly, whether or not to include density dependence in a model needs careful consideration. The decision is likely to be based on both the data available and on the potential impact. One approach can be to develop both forms of model. This often highlights that, across the range of impacts and population sizes being considered, the differences between the models may be trivial. In the absence of direct evidence, the means by which to incorporate density dependence and the demographic rates affected should be based on sound knowledge of the species and the mechanism by which it is likely to operate. Clear discussion of the associated assumptions should be included.

Transferability of demographic rates

2.13 Some seabird species have been well studied over many years and good estimates of average demographic rates and their variances are publically available. However, even in these cases, the study populations will probably not be the ones for which modelling is being considered. Thus, assumptions need to be made about the transferability of demographic rates between populations. Modelling species which have been less well studied is likely to entail further assumptions. These may include the use of demographic rates from different populations or even from related species. The reliability of results obtained from models incorporating data from other species will depend on the similarity of the species in question. Discussion of the potential impacts of such actions should be included.

Model structure

2.14 The level of demographic detail available will also determine the complexity of the model in terms of age or stage structure. Almost all seabird studies are conducted at breeding colonies. They are therefore based on breeding adults. After fledging little is known about most species until they return to breeding colonies either as immature pre-breeders or breeding adults. The level of detail available for different age classes will determine the degree to which the population can be sub-divided into age groups for modelling. A simple formulation comprising two groups, pre-breeders and breeders, may be the most reasonable model structure, in the absence of information on juvenile and immature survival and return rates.

How will model validation be addressed?

- Can the model be developed using one set of data and validated against an independent set?
- A clear statement of model reliability is important to determine the degree of confidence which can be placed in the outputs.

Model validation

2.15 The degree of confidence in a model's predictions is determined in part by its ability to replicate a known historical trend. For example, a model can be developed using data from one location and then used to simulate the trend at another. Alternatively, demographic data collected through individual bases studies (e.g. survival rates derived from leg rings etc.) can be used to produce a model which is then compared against the population's trend. While such validation is not always possible due to a lack of suitable independent datasets, this should not be seen as preventing the use of the population model. However, it is important that this is clearly stated so it can be kept in mind during interpretation of outputs.

2.16 Model validation may also reveal systematic differences between the model and the validation data. If such differences are considered likely to impact the model's predictions then some means to modify the model may be required.

What is the impact of concern?

- Can the impact be reliably quantified?
- Will it impact directly on a demographic rate (e.g. collision mortality) or indirectly via effects on prey or habitats?
- Can the scale of the impact be predicted with confidence, or should a range of possible impact magnitudes be considered?

Can the impact be modelled?

2.17 Prior to development of the population model it is critical that the impact of concern has been assessed in a quantitative manner to generate estimated values for use with the model. In the case of additional mortality (e.g. from collisions with wind turbines) the potential impact has a clear quantitative component which is well documented and straightforward. For other, sub-lethal, impacts it is likely to be less clear how to incorporate the effects quantitatively into the model. Whatever impacts are being considered, the potential for uncertainty in their estimated magnitude should also receive attention. Ideally these can lead to predictions incorporating uncertainty, however if this is not possible then some discussion of how this uncertainty may affect interpretation of the results should also be included.

2.18 For aspects such as displacement or changes in prey abundance or distribution there will need to be a means to generate predictions of the number of individuals affected and the magnitude of the effect size. Since these values are unlikely to be known with any certainty, the most robust approach will be to explore ranges of 'reasonable' values. Indeed, this represents one of the key benefits of population models, as tools to explore a range of possible scenarios. Determination of the 'reasonable' values to use should be undertaken through discussions with the SNCAs and regulators.

What form of output from the model is appropriate for the questions being asked?

- The questions being asked and data available should determine the type of model used but how should the outputs be presented?

2.19 A deterministic model produces the same result for any given scenario, with no variation around that value. A stochastic model produces a 'different' result every time it is run, due to the use of randomly selected demographic rates at each time step. In order to build up a picture of outcomes from a stochastic model, many repeats are required, from which summary statistics (e.g. average population growth rate) and probabilities (e.g. of population decline) are calculated. For both types of model, comparison of outputs from un-impacted (baseline) and impacted model runs can then be made in order to begin assessing the potential effect on the population.

2.20 The number of model runs required to obtain robust results is dependent on the scale of variation in the model (i.e. how variable the demographic rates are) and the magnitude of impact being investigated. All else being equal, a highly variable population (i.e. with large variances) and a small impact will require more simulations in order for the 'signal' to be detected through the 'noise', and vice versa.

2.21 If a deterministic model is used, the output of most value is likely to be the long term population growth rate. The extent to which this varies in response to impacts on the population can be assessed. It is important that this is done in a relative manner, focussed on the *change* in the growth rate, rather than the rate itself, since the latter is potentially less reliable than the former.

2.22 If a stochastic model is used, as well as the stochastic equivalent to the long-term growth rate (the average growth rate), confidence intervals around this figure can be estimated. Outputs can also include the probability of population decline below specific thresholds (quasi-extinction) in response to varying impact sizes. Again, the focus should be on the *change* in the probability of decline, rather than the actual probabilities themselves.

2.23 The first few time steps outputted by a projection model can be heavily influenced by starting conditions (e.g. population age structure). To avoid these affecting the estimated population growth rate it is sensible to estimate the rate with the first few time steps (typically 5 is sufficient to remove any large systematic fluctuations) removed from the calculation.

2.24 Overall, it is worth stressing that the predicted population sizes themselves are of lesser interest than the relative changes predicted to occur due to impacts, and this should be reflected when reporting model results.

3. REFERENCES

Morris, W. F., and D. F. Doak. 2002. *Quantitative Conservation Biology: the Theory and Practice of Population Viability Analysis* 480 pp. Sinauer Associates.