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A Stochastic Collision Risk Model for Seabirds in Flight

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Executive summary

1 Collision Risk Models (CRM) are used to assess impacts on seabird populations in all offshore wind farms Environmental Impact Assessments ('EIA') and Habitats Regulations Appraisals ('HRA') in the UK. Existing models are unable to properly incorporate uncertainty in the input parameters into calculations of uncertainty in the collision prediction and consequently are not expressed in the outputs.

2 Uncertainty in predicted collision has resulted in the delayed deployment of offshore wind projects, with projects being reduced in size or even cancelled. Not incorporating uncertainty when it is known to occur may be failing to meet the requirement from the European Court of justice to use, "…the best scientific knowledge in the field…".

3 This project aimed to create a CRM that incorporates variability in input parameters correctly into a predicted collision impact with estimated variability. In order to produce a model that was fit for purpose, stakeholders were consulted through a questionnaire-based survey.

4 The survey results section was in seven parts, each asking about different aspects of the CRM. These were: CRM concept, user experience, CRM inputs, CRM operation, CRM outputs, CRM error checking and CRM improvements.

5 The survey, while taking in to account the scope of the project, resulted in the following changes requested by stakeholders:

- Create a user-friendly interface for non-R users;
- Speed up the code;
- The number of turbines should be a user input;
- Output predicted collision probability data;
- Seasonal (as well as monthly & annual) assessment (default + user defined);
- Error checking inputs and collision probability; and,
- Monthly or seasonal flight height inputs.

6 The new stochastic CRM (sCRM) was based on the code written by Masden (2015), but had to be compatible with the Band (2012) offshore CRM. Testing showed that the predictions of the Masden (2015) code matched the predictions of the Band (2012) Excel spreadsheets for Option 1, but that differences in outputs for Options 2 and 3 arose because of a calculation error in Masden (2015) code. Consequently, the sCRM was based on an updated, and streamlined, version of the Masden (2015) code.

The new sCRM was produced in two forms: Firstly, a Shiny app based on the R-code, available as an online tool, which can be run from:

https://dmpstats.shinyapps.io/avian_stochcrm/

Secondly, the Shiny app can be downloaded as a package and run locally in a browser. It can be downloaded from:

https://github.com/dmpstats/stochCRM

1 Introduction

7 Collision Risk Models ('CRMs') have been used to assess impacts on bird populations in all offshore wind farms Environmental Impact Assessments ('EIA') and Habitats Regulations Appraisals ('HRA') in the UK since 2009. These types of models have also been used in onshore wind farm EIA and HRA since the early 2000s, with further models being produced since then to address various issues (Masden & Cook 2016). They have become a *de facto* requirement of Environmental Statements and Appropriate Assessments ('AA') in the United Kingdom.

8 CRMs as an impact assessment tool began with the production of the Scottish Natural Heritage ('SNH') (Band 2000, Band *et al.* 2007) model, which is an application of the concept first published by Tucker (1996). It is a simple mechanical model that calculates the probability of a bird of a certain size moving at a set speed through a wind turbine rotor, being struck by a turbine blade of a certain size and moving at a set speed. Since it is a simple mechanical model of two bodies in motion it does not account for bird behaviour in avoiding the wind farm, or a turbine or the rotor blade itself. These elements of bird behaviour (as well as any errors in the calculation) should, hypothetically, be taken into account by applying an avoidance rate (typically 95% or higher). The Band (2000) model was designed for onshore wind farms where data on bird flight activity is collected by observers carrying out behavioural observations prior to the wind farm be constructed. However, the data required to characterise the ornithological interest in an offshore wind farm makes use of very different data. Boat based or digital aerial surveys are undertaken to estimate species density. It was therefore necessary to adapt the SNH (2000) model to use this type of data.

9 This was undertaken by Bill Band (the original author of the SNH (2000) model), for The Crown Estate Strategic Ornithological Support Services ('SOSS'), under the Round 3 enabling actions. This new model, like the SNH (2000) model, was provided in Microsoft Excel spreadsheets and was deterministic (Band 2012). While the guidance to the Band (2012) model did suggest an approach to incorporate variation around input data, the method was not statistically valid as it assumed that each variable was independent (Masden 2015), and there were errors in the assumed levels of variability around some input values.

10 The limitation of the Band (2012) model in incorporating input value variability and uncertainty led to Masden (2015) developing a stochastic version of the Band (2012) model. In addition to incorporating data uncertainty in to the model, the Masden (2015) version also coded the calculations in to R code (http://www.r-project.org). However, while Masden (2015) successfully achieved the coding of the Band (2012) model and incorporating uncertainty, users have noted various flaws in running this code. This culminated in a review of the Masden (2015) version of the model by Trinder (2017).

11 The main findings of Trinder (2017) were that the Masden (2015) coded version of Band (2012) has the following constraints:

- The use of only normal distributions or truncated normal distribution for all variables was inappropriate;
- Turbine parameters are modelled with uncertainty, which does not meet the requirement to follow a 'Rochdale envelope' approach to consenting;
- The Masden (2015) code did not allow bird aerial densities to exceed two birds per km^2, which was unrealistic;

- The model *always* uses the generic wind speed, rotor speed, blade pitch relationship provided, and this cannot be 'switched off'; and,
- The method used to generate a range of proportions of birds at collision risk height *can* generate negative values.

12 In most circumstances, the deterministic outputs from the SOSS CRM have been sufficient for determining no likely significant effect on the environment, for EIA, or no adverse effect on site integrity, for an AA. In most cases, for most species, it can be clear that, even with a worst-case scenario used as input parameters, the predicted impacts are relatively small. Uncertainty in CRM can have large impacts on the deployment of offshore wind projects; e.g. the Docking Shoal project was refused consent in July 2012 based on the outputs of CRM, and subsequent population modelling, and it is therefore essential that models are able to be relied upon by developers, regulators and advisers. As the number of developments increases this will be applied increasingly via cumulative impact assessments.

13 However, there have been increasingly frequent situations where CRM predictions have come very close to significant impacts. In these situations, an over-reliance on a single-value CRM prediction can lead to problems, even when a worst-case scenario is presented. Thus, an understanding of the variability around input values and their effects on the potential range of output values can be very important. Existing case law suggests that the approach using a single, precautionary, value may not be wholly compatible with the purpose of the European nature directives.

14 The European Court of Justice ('ECJ') Case C-127/02 states that an appropriate assessment should be made, "…in light of the best scientific knowledge in the field.". It could be argued that a deterministic CRM is not making use of the "best scientific knowledge" as it is known that input values are variable, and the only approach to use in these situations is potentially unrealistic worst-case scenarios. A stochastic CRM would not have these problems, as it would incorporate the variability in the data and present a result with levels of uncertainty. Thus, worst case scenarios can be avoided and the best scientific knowledge in the field can be used appropriately. Outputs from a stochastic CRM can then be used as a mortality input, with known variability, for stochastic population models. These can be used for predicting the importance of the impact on populations for either EIA or HRA.

2 Aims of this project

15 The research aim of this project was to develop a stochastic version of the Band (2012) collision risk model in R that would incorporate the gaps identified by industry and statutory agencies, providing a more robust and transparent method of accounting for uncertainty in the estimation of seabird collision rates.

2.1 Objectives

16 The research objectives for this project were:

- Identify current gaps in Band (2012) model and Masden (2015) code to be addressed in an R-based stochastic version.
- Produce an R-based stochastic version of Band model, tested against the existing Excel version, with R code independently validated.
- Provide advice on the most appropriate parameterisation of the model produced, accounting for limited information that may be available for some variables and the rapidly evolving wind turbine generator technologies.
- Consider end-users' needs and ensure that outputs presented from the model were in an appropriate form.

3 Stakeholder engagement

17 Positive stakeholder management and consultation is the identification, analysis, planning and implementation of actions to allow clear and open engagement with stakeholders. In this instance stakeholders were individuals or groups with an interest in the project, 'A stochastic collision risk model for seabirds in flight', because they are involved in work on this topic or may be affected by the outcomes from the consultation process.

18 Stakeholder management, and management of aspirations there-in, is a challenging aspect with any consultation. The overall project can be undermined if there are significant areas of confusion with poor stakeholder commitment and a lack of clear engagement, emphasising the need for clear documented communication.

19 The final draft pro-forma questionnaire was therefore fully discussed with the Project Steering Group ('PSG') prior to distribution, with several changes being made.

3.1 Questionnaire

20 A stakeholder questionnaire was designed to capture responses on all the current CRM inputs and outputs, where there are limitations and how stakeholders think these should be addressed. Questionnaires were provided as PDF forms (see Appendix 1), that could be printed and completed by hand or electronically, or via an online survey using Google Forms. Stakeholder responses were also followed up with a telephone interview for a cross-section of stakeholders (Appendix 2).

21 Responses were analysed using descriptive statistics and qualitative analysis, to determine the gaps in existing CRMs and stakeholder needs.

22 Data collected from respondents was anonymised and analysed to determine the key changes needed to be made to the current CRM.

23 Analysis of pro-forma data involved quantitative descriptive statistics and qualitative analysis of free text responses. This included analysis of the response rate, most important concerns about input data, most common concerns about outputs and the most common requested changes to the CRM. These were analysed as a whole for all respondents. Free text was summarised and descriptive assessment of common themes undertaking using word clouds.

24 In addition to the questionnaire a selection of stakeholders were invited to participate in a follow up interview by telephone. This was to ensure that the questionnaire was capturing all of the responses from stakeholders necessary to identify the needed improvements in a stochastic CRM.

3.1 Survey results

25 Survey results were split into seven sections, each asking about different aspects of the CRM. These sections were:

- CRM concept;
- User experience;
- CRM inputs;
- CRM operation;
- CRM outputs;

- CRM error checking; and,
- CRM improvements.

3.1.1 CRM concept

26 There was only one question, Question 1, in this section.

27 Question 1 was in two parts. The first part of the question, 1a, asked, “Do you think that CRM is a useful method for assessing potential impacts from offshore wind farms?”

28 This question was to determine if stakeholders thought that collision risk modelling was a useful method when used for impact assessments. In addition, it provided important context to a stakeholder’s views that could affect their responses to other questions.

29 Stakeholders were provided with three possible responses:

- Yes;
- No; and,
- Don’t know.

30 All responses were “Yes”, though two responses provided qualification on their response. One stakeholder noted that there was too much emphasis on CRM results and that they tended to be taken too “literally”. The other response was similar, noting that the value of CRM output depends on how they are used; if as an absolute measure of risk to birds, CRM was not considered useful, but as a relative measure it was considered useful.

31 The second part of question 1 was a free text option, “If you answered "Yes" to Question 1a, please describe the benefits of CRM. If you answered "No", please describe why you think that CRM is not a useful method.”

32 Most responses were positive (56%) and were mostly in relation to the existing CRM being quantitative, transparent and consistently applied. Many positive responses highlighted the CRMs value in providing relative impact between turbine scenarios or between projects. Its value as a cumulative impact tool was also mentioned several times.

33 A large proportion of responses (40%) provided comments containing both positive and negative comments. Negative comments were focused on issues around too much use of absolute, rather than relative, impact calculations. Many stakeholders were concerned that CRM outputs tended to be considered as more accurate a measure than the input data suggest. Only one comment (4%) was wholly negative.

34 Analysis using a word cloud (Figure 1) highlights that responses were not entirely positive or negative. The words “provides” and “potential” were common, as were “data”, “impacts” and “risk”. This matches the findings that more comments were positive, and that they were focused on CRM being useful for assessing potential impacts on birds.

Figure 1 Word cloud analysis results of responses to Question 1b.

3.1.2 User experience

35 There were four questions in the section on user experience. This was split between questions about experience using the Band (2012) and Masden (2015) models, and general use of R-code.

36 Question 2 was also in two parts. The first part of the question, 2a, asked, "How would you describe your primary role in using the Band (2012) CRM for offshore wind farms? (Tick both user and interpreter boxes if appropriate)"

37 This question was asked to determine stakeholders' level of understanding of collision risk modelling and their ability to knowledgably answer questions or provide feedback.

38 Stakeholders were provided with two possible responses

- Model user; and,
- Model output interpretation.

39 Valid responses were either of these options or both. The field was not mandatory, so users could provide no response. Stakeholders were then given further options depending on which of the above options they chose. For model users, there were four possible responses:

- Expert;
- Occasional;
- Basic; and,
- None.

40 For model output interpretation, there were three possible responses:

- Supervisory;

- Reviewer; and,
- None.

41 Those that chose "None" were asked to describe their use of the Band (2012) model. Most stakeholders described themselves as both model users and model output interpreters (Figure 2). There were slightly more stakeholders that described themselves as only undertaking model output interpretation (20%), than only model use (12%). Only 2 stakeholders (8%) did not provide a response.

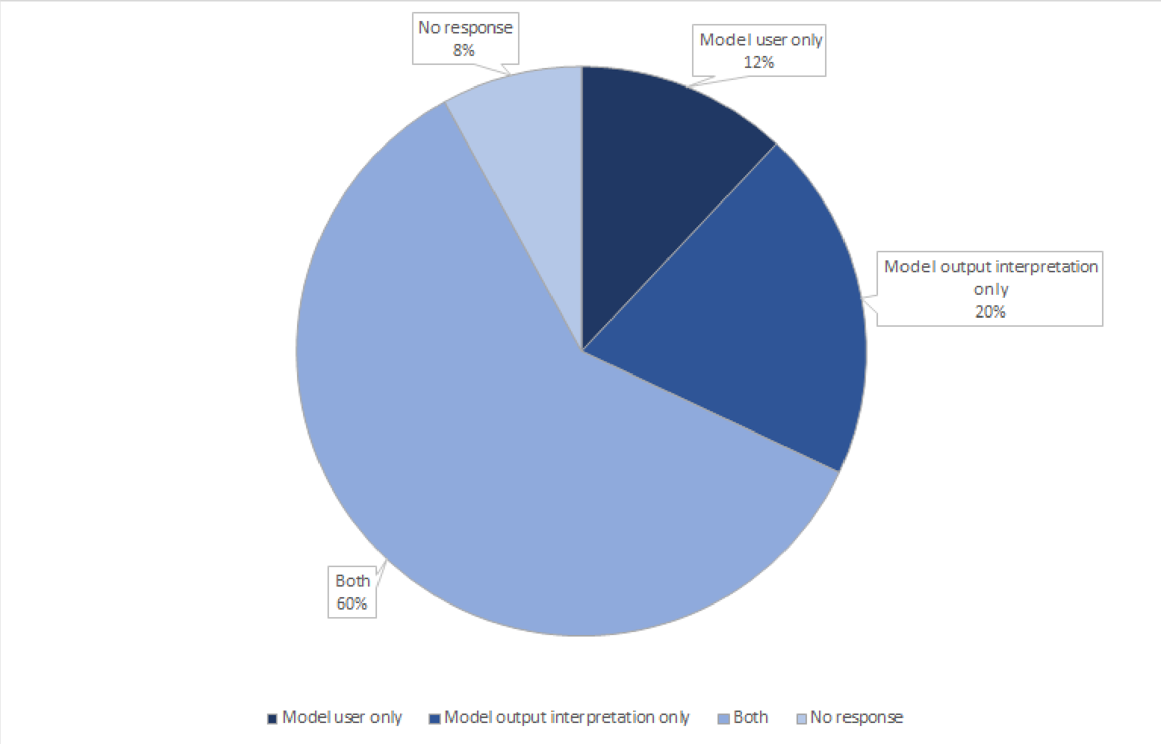

Figure 2 Relative proportion of stakeholder responses to question 2a, Part I.

42 The responses to this part of Question 2 indicated that most stakeholders responding to the survey were well aware of the Band (2012) CRM in some capacity and were therefore likely to provide useful feedback.

43 Among those that described themselves as model users, the majority (46%) described themselves as "Expert" users (Figure 3). Small proportions described themselves as "occasional" or "basic". A relatively large proportion (25%) did not provide a response, but these were mostly stakeholders that described their experience as only with model output interpretation.

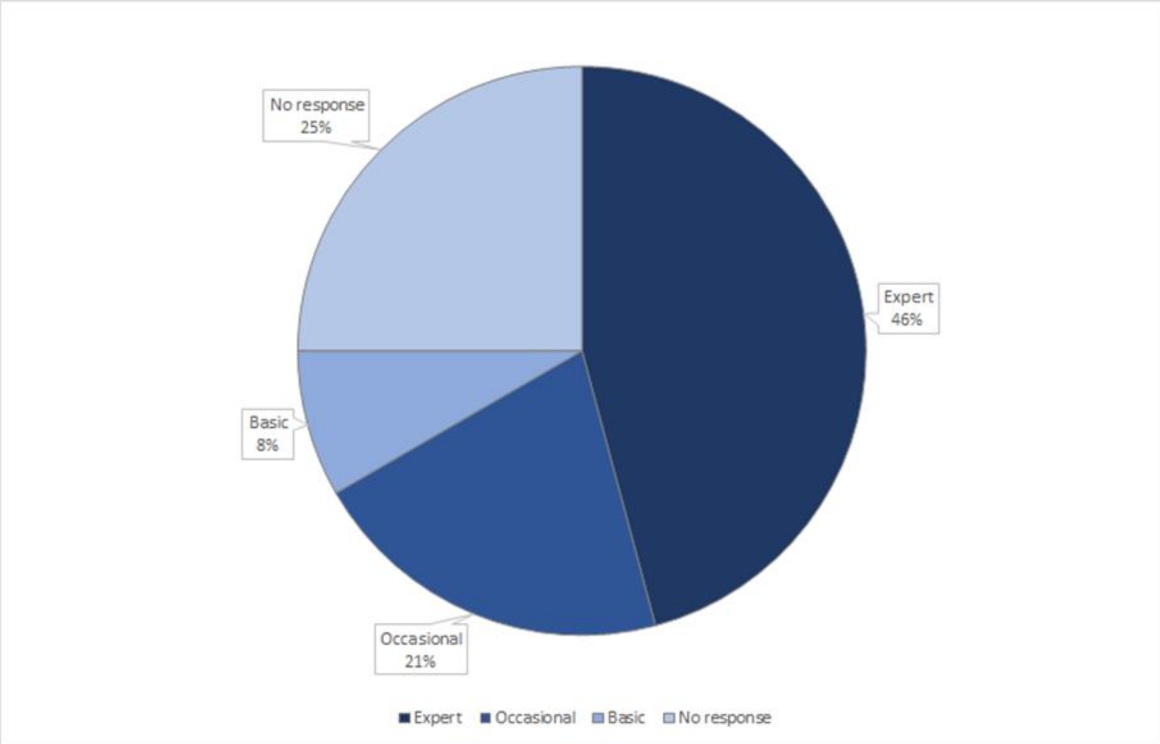

Figure 3 Relative proportion of stakeholder responses to question 2a, Part II.

44 Of those stakeholders that described themselves as being involved with model output interpretation, almost half (48%) were reviewers only of model outputs (Figure 4). Almost one third (28%) were either only supervising model output interpretation or were involved in both reviewing and supervising model output interpretation. Three stakeholders provided the response "other", and three did not provide a response, but these had not selected "model output interpretation" as a response. The free text

responses from three stakeholders only provided confirmation of their status from the categorical responses, so did not provide any further relevant information.

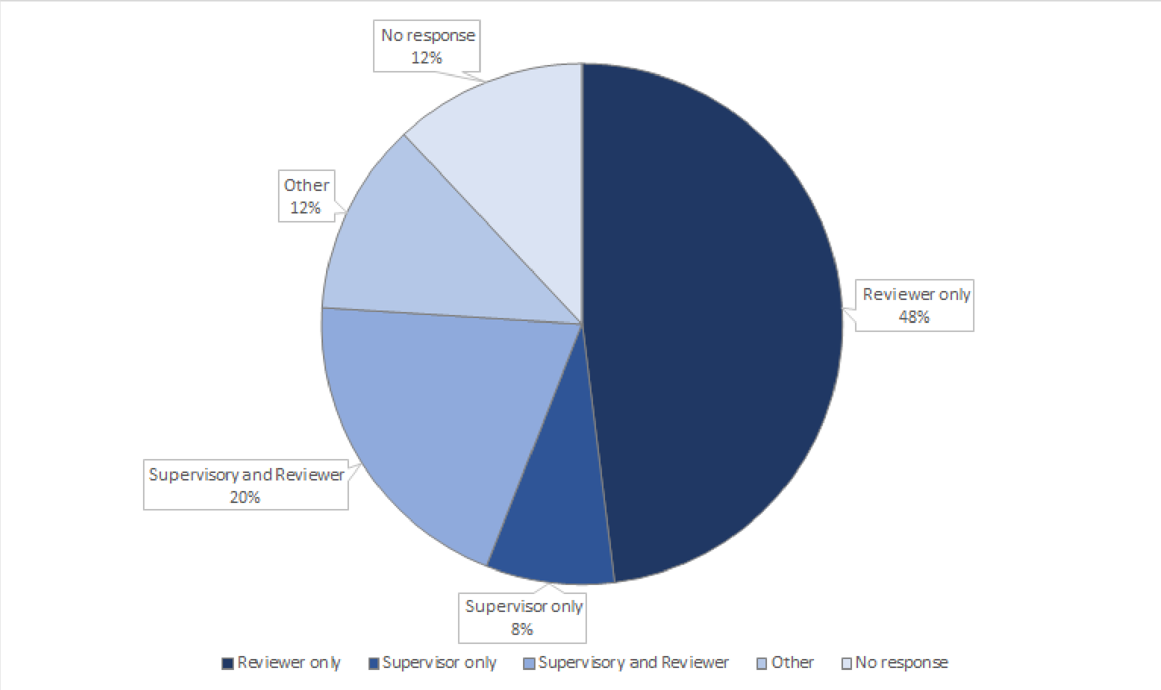

Figure 4 Relative proportion of stakeholder responses to question 2b.

45 Question 3 was a single part question, "What level of R user do you consider yourself to be?". This question aimed to determine stakeholders' level of understanding of the coding language to be used for the stochastic CRM and their ability to knowledgably answer questions or provide feedback.

46 Stakeholders were provided with five possible responses:

- Expert;
- Regular;
- Occasional;
- Never; and,
- Other.

47 Those that chose "other" were asked to provide further information in a free text box. The most common response from stakeholders was that they had no experience of using R (44%), with a relatively high proportion only using it occasionally (24%) (Figure 5). Almost a quarter of responses (24%) were from stakeholders that described themselves as expert or regular users of R.

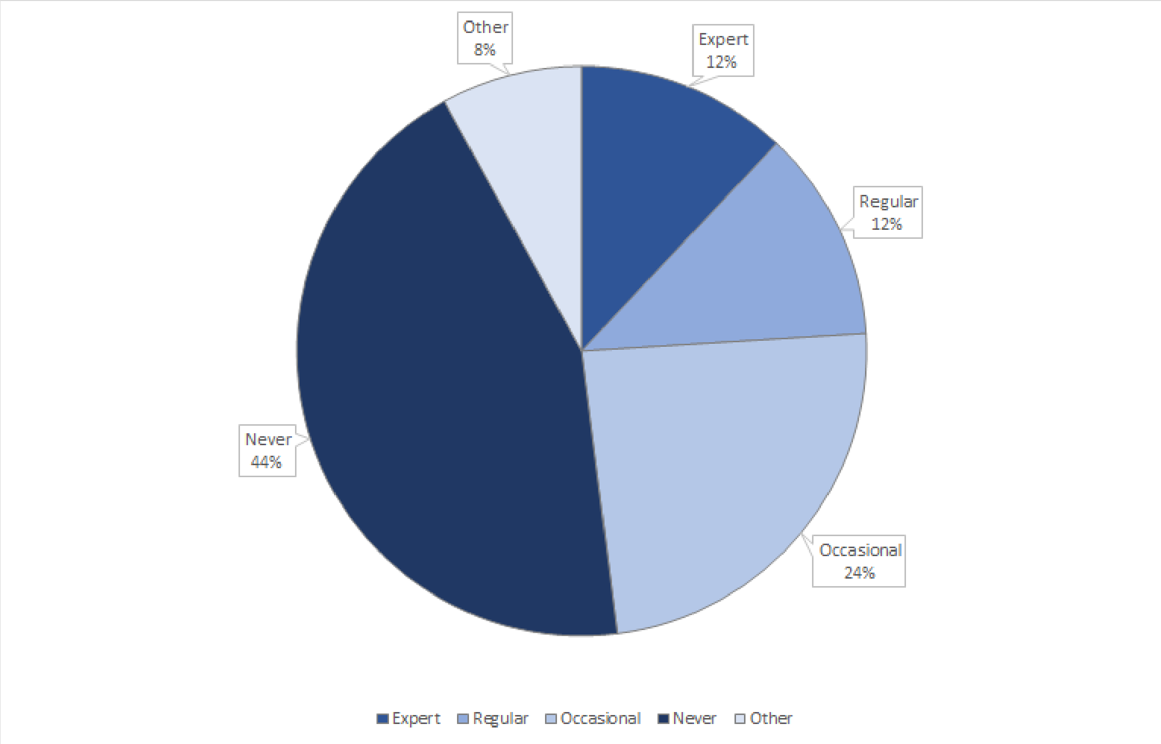

Figure 5 Relative proportion of stakeholder responses to question 3.

48 This made it clear that most stakeholders that responded were unlikely to make a lot of use of an R-code only version of a new stochastic CRM.

49 Question 4 was also a single question, "Have you ever used the Masden (2015) stochastic CRM (or another stochastic CRM) in R?"

50 This question was also to determine stakeholders' level of understanding of CRMs in R, rather than only in Excel, and their ability to knowledgably answer questions or provide feedback. Stakeholders' were provided with four possible responses:

- Yes (Masden (2015) CRM);
- Yes (another stochastic CRM);
- No; and,
- Other.

51 Responses were divided between a majority (60%) that had never used the Masden (2015) CRM, and a large minority (40%) that had. No stakeholders had used any other stochastic CRM, and there were no "other" responses (Figure 6).

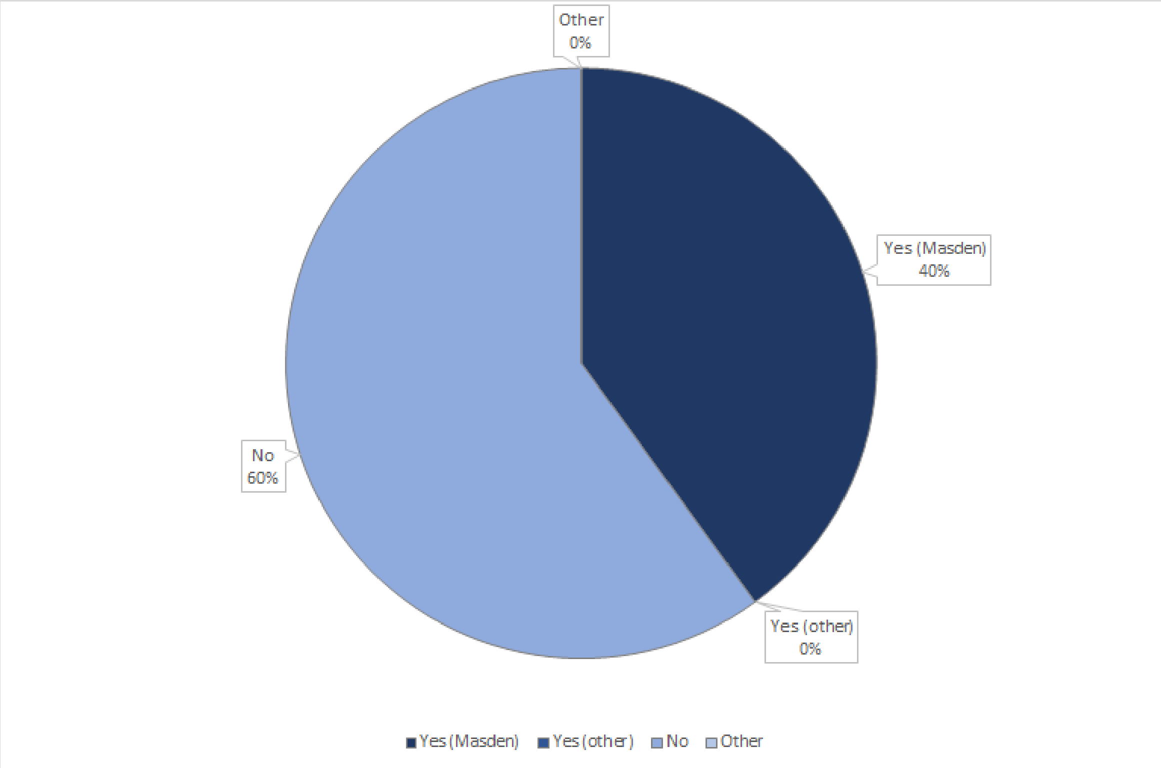

Figure 6 Relative proportion of stakeholder responses to question 4.

52 Question 5 was also a single question, "Have you ever experienced issues running the Masden (2015) stochastic CRM (or another stochastic CRM) in R?" This question aimed to draw out any currently unknown problems with the Masden (2015) version of the CRM.

53 Stakeholders were provided with three possible responses:

- Yes;
- No; and,
- Don't know.

54 A free text box was provided asking those who responded "Yes" to provide further information.

55 While the majority of responses (Figure 7) were either "Don't know" or "No response" (36% and 28% respectively), most responders with a known response had experienced problems with the Masden (2015) version of the CRM (28%).

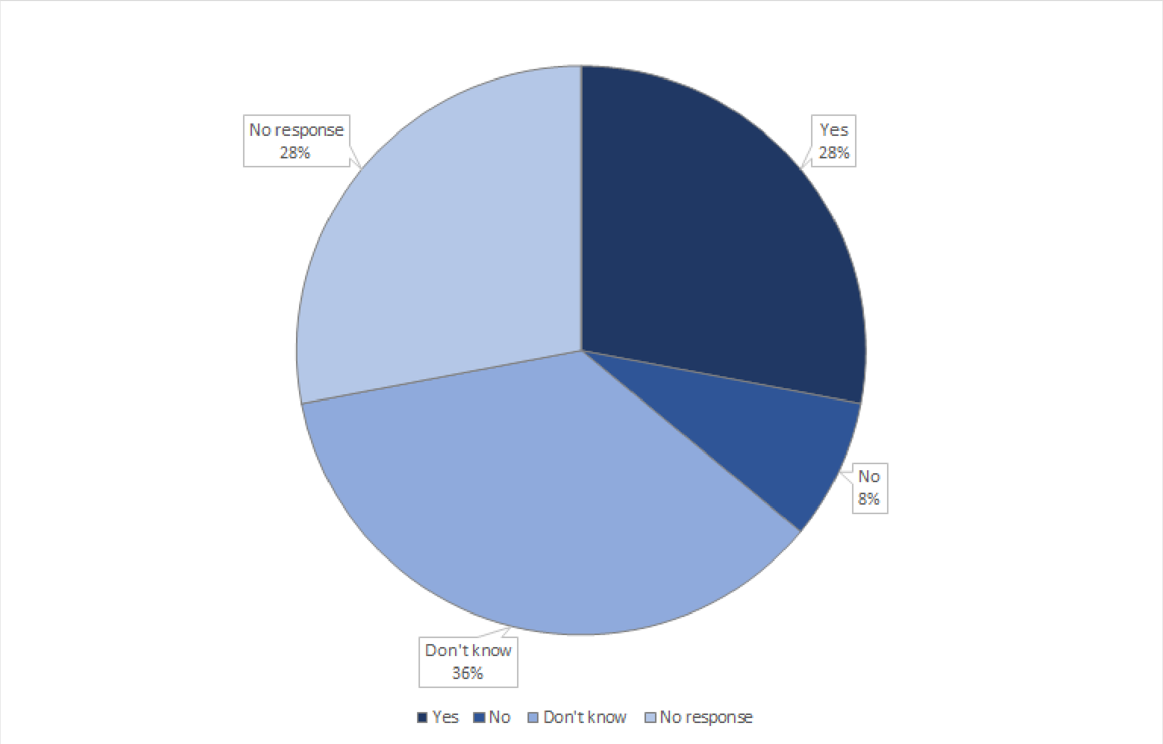

Figure 7 Relative proportion of stakeholder responses to question 5

56 Free text responses were often in relation to bugs in the code, the probability distributions used for count data, the way that the number of turbines is calculated, the assumed relationship between wind speed, rotor speed and blade pitch and the speed to run the model. Useful other comments included issues with selecting appropriate proportions at collision height, variation being present of fixed parameters (e.g. blade length will effectively have no variation around it) and the difficulty experienced when trying to run multiple turbine parameters.

57 Word cloud analysis (Figure 8) of the free text responses agreed with the above assessment with “code”, “input” and “parameters”, and “problems” being commonly expressed.

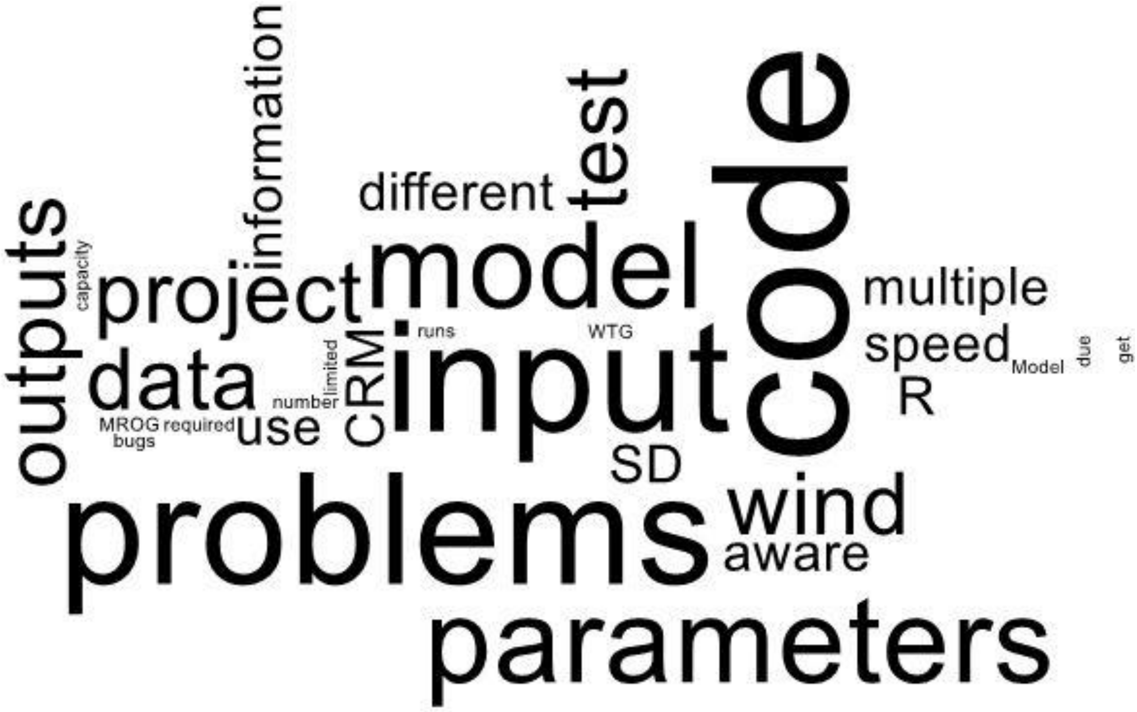

Figure 8 Word cloud of the free text component of question 5

3.1.3 CRM inputs

58 There was only one question in the section on CRM inputs, Question 6.

59 Question 6 was also a single part question, "Are there any Band (2012) input values for birds (e.g. wing span, length, flight speed, nocturnal activity) that you think should be changed, improved or added?"

60 This question aimed to ensure that as many improvements as possible were included in the new model. Stakeholders were provided with three possible responses:

- Yes;
- No; and,
- Don't know.

61 A free text box was provided asking those who responded "Yes" to provide further information. There was a strong, positive, response from stakeholders (76%) to this question (Figure 9). With only 12% stating that there were no changes needed to the bird input parameters.

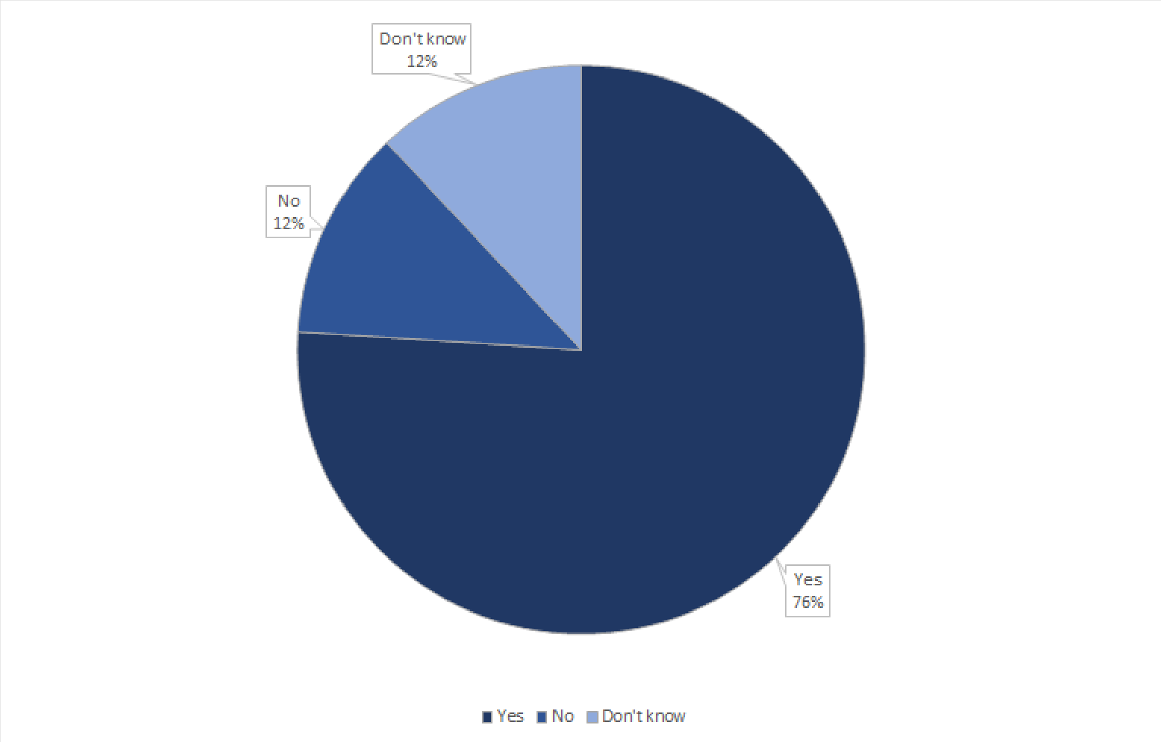

Figure 9 Relative proportion of stakeholder responses to question 6

62 The free text responses from those that stated "Yes" were commonly in relation to flight speed data and nocturnal activity data. Responses suggested that existing data were of poor quality (small sample sizes) or poor resolution (broad categories for nocturnal activity) or both. Other useful comments centred around the lack of behavioural responses in the model (e.g. changes in bird speed, height, etc. in relation to weather). There were also comments that the model is unrealistic in dismissing the effect of different angles of approach to the rotor, though one stakeholder commented that this was not really a bird input parameter issue, but a model calculation issue.

63 Word cloud analysis confirmed much of the above assessment, with "flight", "values", "bird" and "nocturnal" the commonest words used. "Activity", "speed", "model" and "data" were also commonly used.

Figure 10 Word cloud of the free text component of question 6

3.1.4 CRM operation

64 There were three questions in the section on CRM operation. These were related to how the CRM does, or should, predict the number of collisions.

65 Question 7 was also a single part question, "Should the new stochastic CRM retain all of the model Options (1, 2, 3 & 4) described by Band (2012)?"

66 This question aimed to gauge whether stakeholders wish to see changes in the approach used for modelling the different options. Stakeholders were provided with three possible responses:

- Yes;
- No; and,
- Don't know.

67 A free text box was provided asking those who responded "No" to provide further information. There was a clear response from stakeholders, with 64% wanting to retain the four model Options available in the Band (2012) CRM (Figure 11). Roughly the same number of stakeholders responded "No" as "Don't know".

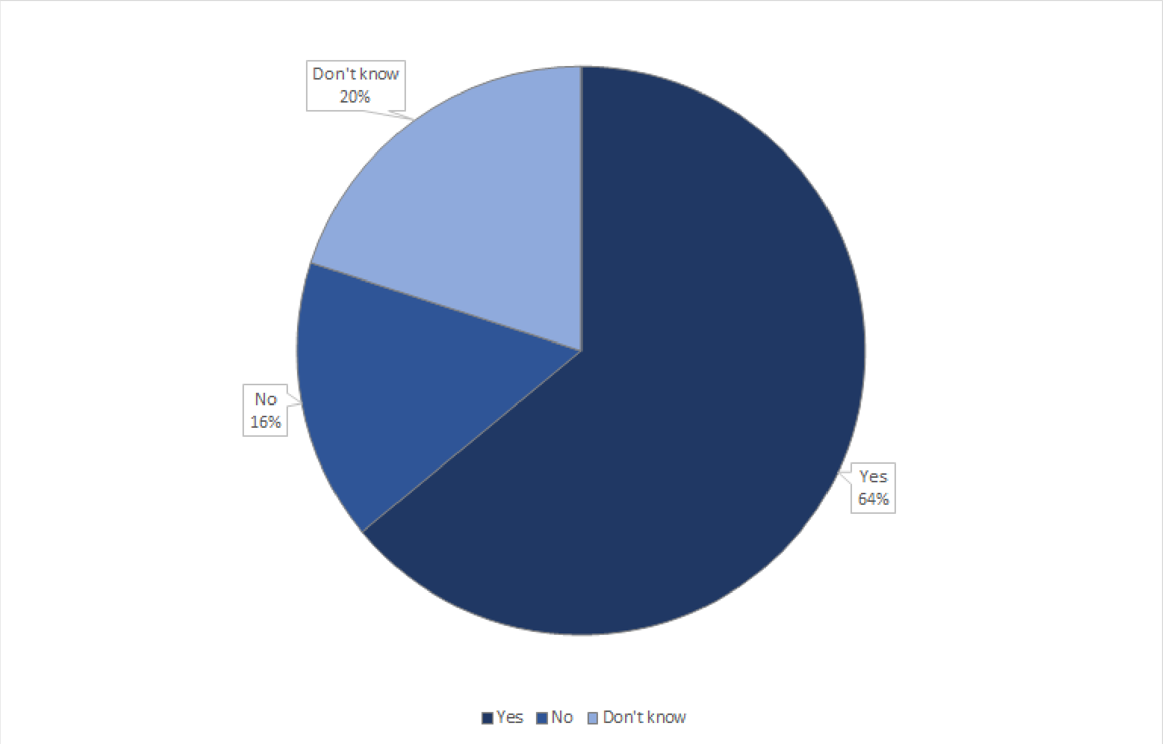

Figure 11 Relative proportion of stakeholder responses to question 7

68 While the questionnaire asked for further information only if the stakeholder responded "No", two of the six responses were from stakeholders who responded "Yes". Both responses noted that all options should be retained for making comparisons with older assessments, so these responses were still very useful. There was no consistent response from stakeholders, with some wanting to drop Option 3 & 4 (extended model), and some wanting only Options 1 & 3. One comment was that if the model is to be stochastic, then only the extended model should be used, as this is the most realistic calculation, as it takes into account the skewed flight height distribution of most seabirds.

69 Question 8 was also a single part question, "The Masden (2015) CRM includes the relationship between wind speed, rotor speed and blade pitch. Given the commercial sensitivity of this information, should a precautionary generic approach be used or should turbine specific data be used for consent applications?"

70 There has been criticism of this approach (particularly the access to suitable turbine data at a pre-consent phase). So was considered important to ask the wider community of stakeholders the implications of either not including this approach, or the potential uncertainties in using generic data.

71 Stakeholders were provided with four possible responses:

- Precautionary generic approach;
- Turbine specific approach;
- Don't know; and,
- Other.

72 A free text box was provided asking for any further information on why the stakeholder gave the response they did.

73 There was roughly an equal split between "precautionary generic approach", "turbine specific approach" and "other". A relatively small proportion (8%) of stakeholders responded "don't' know" (Figure 12).

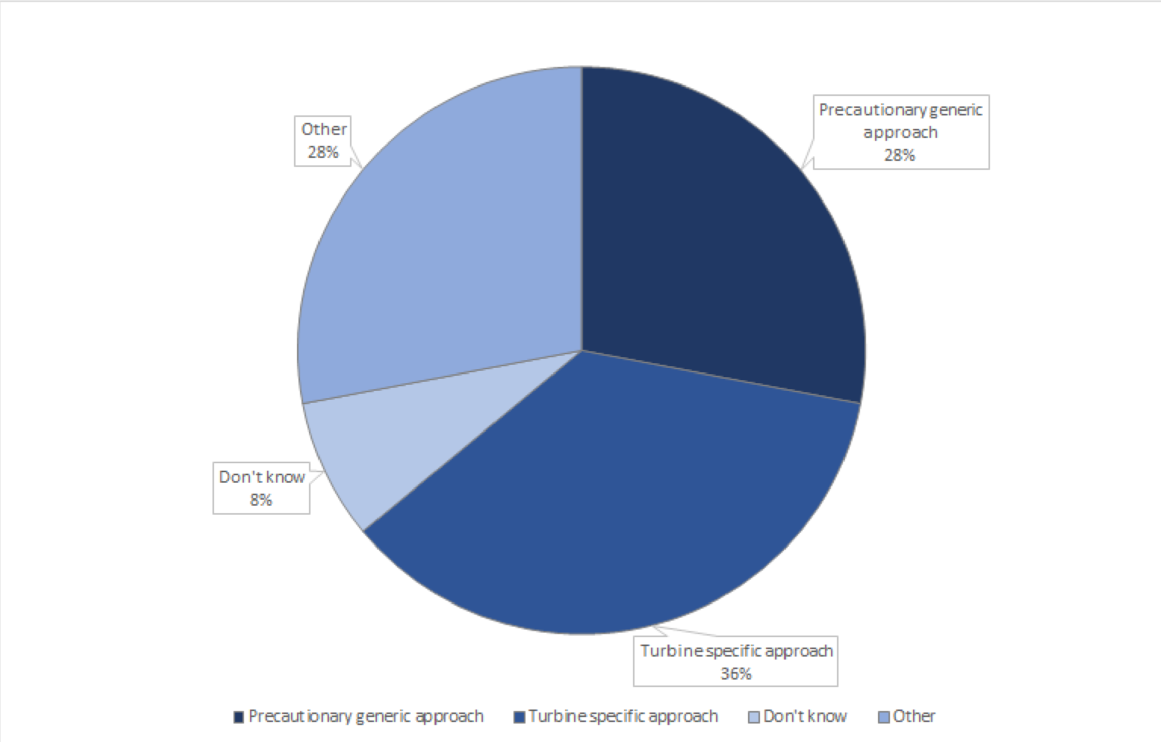

Figure 12 Relative proportion of stakeholder responses to question 8

74 Free text responses were very helpful, with most comments asking for both options to be available, even when stakeholders had selected either a precautionary generic approach or a turbine specific approach. Comments were also provided to highlight the issues around the commercial sensitivity of these data at a pre-construction stage, both from a developer's perspective, and a turbine manufacturer's perspective. Several comments received were about the need to provide these data and how these assessments should be undertaken, were beyond the scope of this project and were issues for regulators and their advisors to consider (e.g. Rochdale envelope approach to a generic or specific approach).

75 In this case, word cloud analysis (Figure 13) did not provide much useful additional value, as most of the commonly used words were from the question itself.

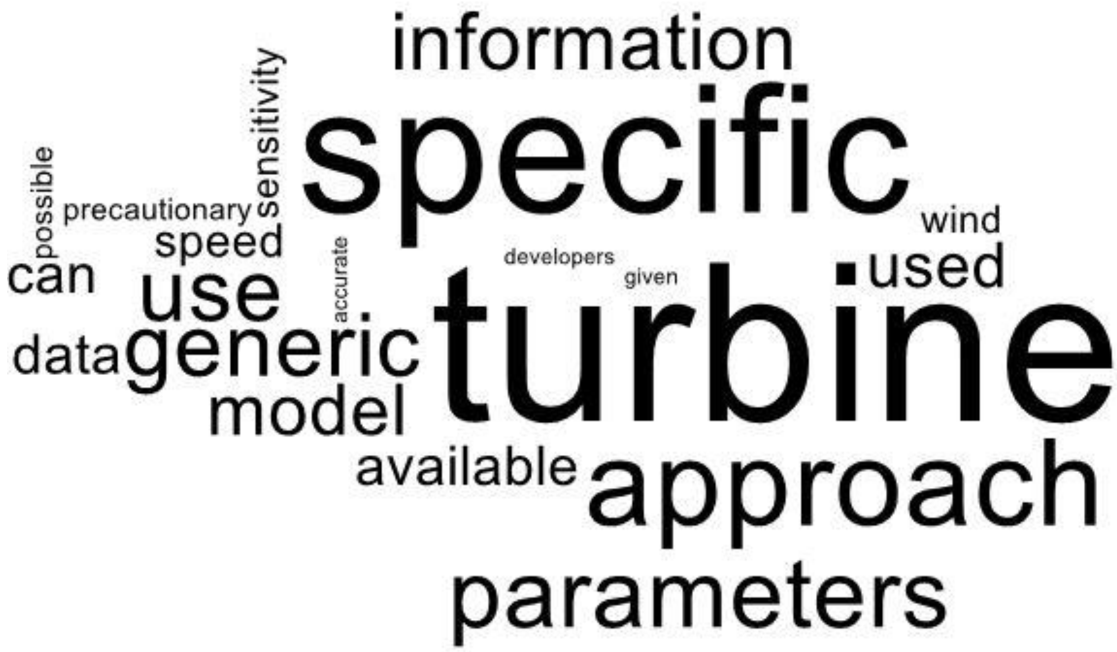

Figure 13 Word cloud of the free text component of question 8

76 Question 9 was also a single part question, "Do you think that the Band (2012) model (& Masden (2015) model) correctly calculates the probability of collision BEFORE avoidance rates are applied?"

77 It has been suggested, several times, in the past that the basic model calculations should be carefully checked by persons with a good understanding of mathematics. This may have been done, so it could be valuable to ask stakeholders this, in case someone has undertaken this check.

78 Stakeholders were provided with three possible responses:

- Yes;
- No; and,
- Don't know.

79 A free text box asked stakeholders that responded "No" why they think that the model does not make the correct calculation.

80 Almost half (48%) of the responses were "No", that stakeholders did not think that the model made the correct calculation for the probability of collision (Figure 14). Only 16% responded that the model did make this calculation correctly, and more than a third (36%) did not know.

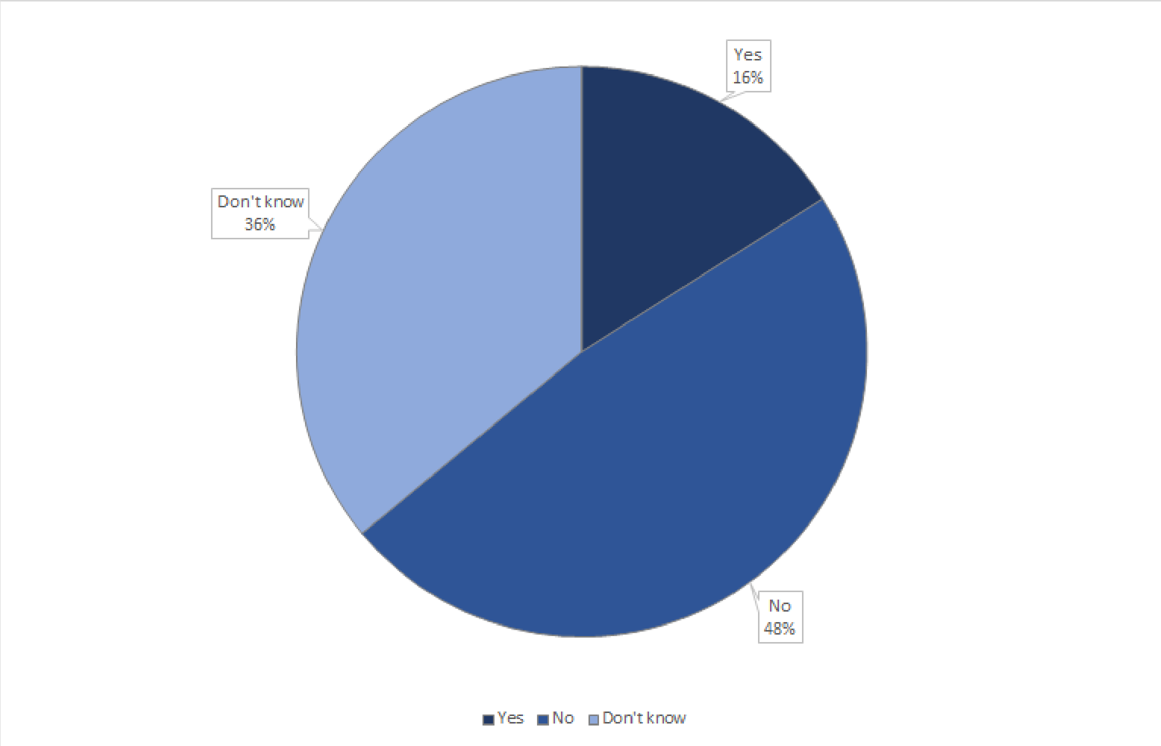

Figure 14 Relative proportion of stakeholder responses to question 9

81 Many of the free text responses commented that the calculation is a simplification and that as it is "just a model" it is by definition, likely to be wrong. Several other comments stated that the model was the best available, so within the assumptions made by the model it was making the correct calculations. Comments also included issues with the assumed 90° angle of approach, the lack of bird behaviour aspects and weather influences captured by the model. One comment suggested that the model flux calculation was likely to be incorrect as it's unbounded (in comparison to flow calculations). Overall, most comments, and the categorical responses, suggest that the question was inappropriately worded, as it was intended to draw out issues with the underlying mathematics, rather than other issues, such as available inputs.

Figure 15 Word cloud of the free text component of question 9

3.1.5 CRM outputs

82 Question 10 was the only question in the section on CRM outputs.

83 Question 10 was also a single part question, "Are there any outputs from the Masden (2015) model not currently provided that may be useful to include in a future model? (A description of the outputs is provided in paragraph 6 of the introduction)"

84 This was an open question to gather information on outputs that have not been considered to date. Stakeholders were provided with three possible responses:

- Yes;
- No; and,
- Don't know.

85 A free text box asked stakeholders that responded "Yes" to provide the outputs that they considered useful.

86 Almost half of stakeholder responses were "Don't know" (48%), which is likely a reflection of the relatively small proportion of stakeholders who had used the Masden (2015) model. The remaining half of responses were approximately evenly split between "Yes" (24%) and "No" (28%) responses. All those that responded "Yes" provide some free text responses, and some "Don't know" responses also provide free text responses. The "Yes" responders requested improved outputs that include tabular data on probabilistic collision outputs (that are currently only provided as plotted data), improved box plot outputs (to include 95% confidence intervals), summarised input information and the predicted number of birds that do not collide in addition to the predicted number that do collide. The "Don't know" responses were limited to a request for probabilistic outputs rather than a single value (which the Masden (2015) model already does), and for sensitivity testing of the new stochastic CRM.

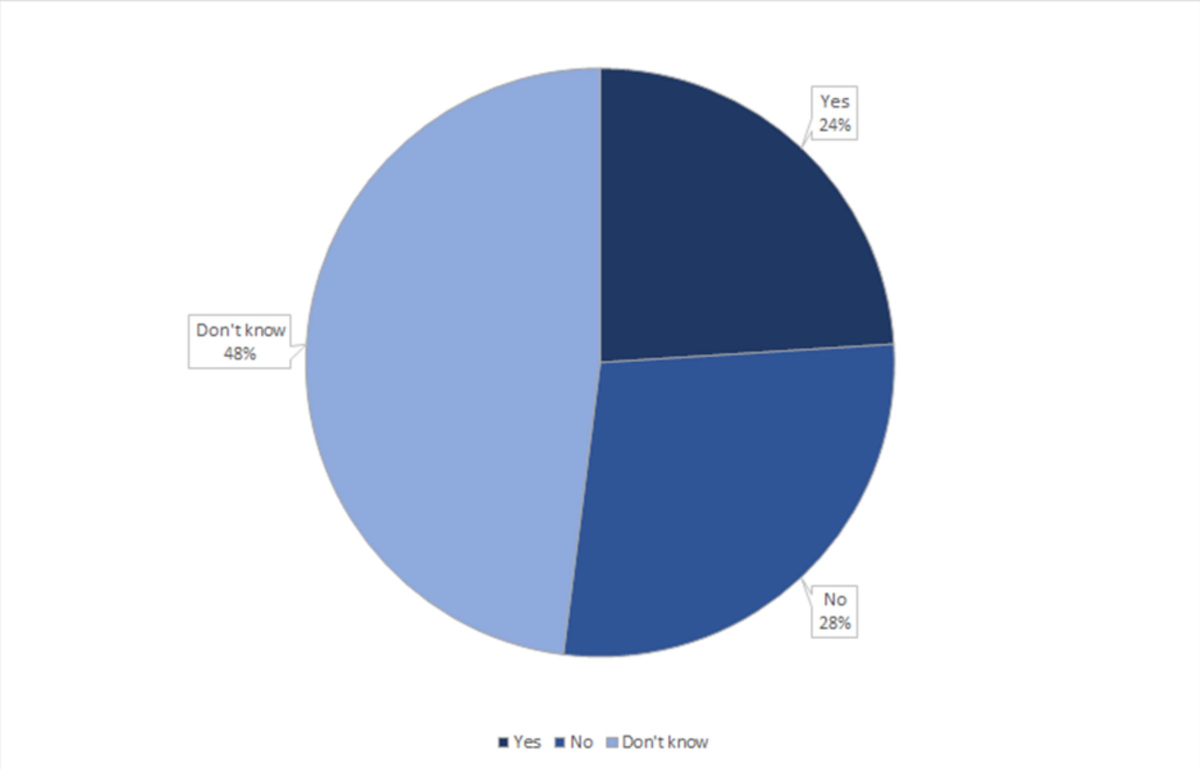

Figure 16 Relative proportion of stakeholder responses to question 10

87 The analysis of free text using a word cloud was not useful for Question 10, as response were too variable to find common themes.

3.1.6 CRM error checking

88 The only question in the section on error checking was Question 11.

89 Question 11 was also a single part question, "The current Band (2012) and Masden (2015) models do not provide any error checking. Is there any turbine specific error checking that would be useful to include in an updated Stochastic CRM?"

90 This question was particularly aimed at developers, hence the focus on turbine error reporting. It was agreed that there was sufficient ornithology expertise within the project steering group to provide advice on matters relating to the bird parameters in the model, but effectively no technical wind turbine experience. Stakeholders were provided with three possible responses:

- Yes;
- No; and,
- Don't know.

91 A free text box asked stakeholders that responded "Yes" to provide examples of useful error checking. Almost two thirds (60%) of stakeholders responded, "Don't know", which was likely a reflection of the nature of the question being turbine specific (Figure 17). About one quarter (28%) of respondents responded "Yes" and only 12% responded "No".

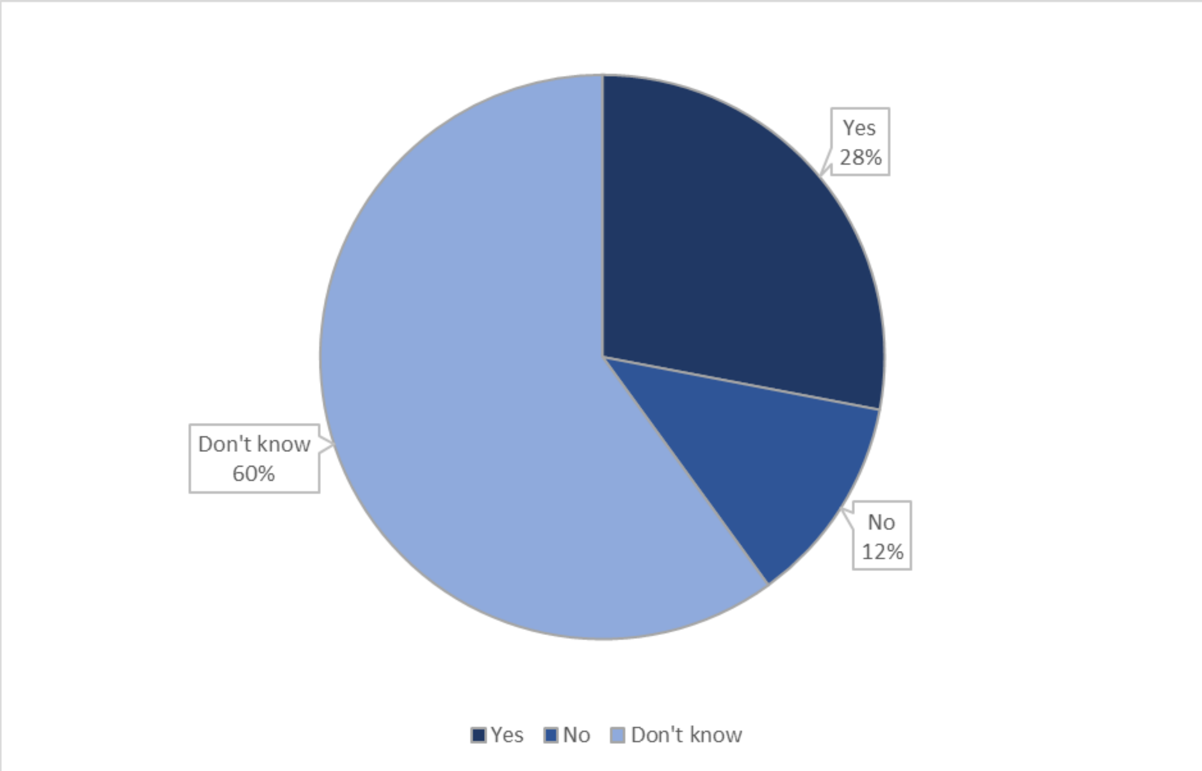

Figure 17 Relative proportion of stakeholder responses to question 11

92 Free text responses included requests for the model to flag up when parameters appear out of range, checking the numbers of birds estimated to pass through the rotor with the available population as a sense check and responses that indicated that the question did not provide an adequate explanation of its intended purpose to stakeholders'.

3.1.7 CRM improvements

93 There were two, free text only, questions in the section on CRM improvements, which were asking general questions and allowed stakeholders to provide any feedback they wished.

94 Question 12 was a single part question, with free text only, "What would be the main improvements you would like to see to a stochastic CRM? Please provide your order of preference/importance (highest first)." This question aimed to draw out practical changes that stakeholders think may be valuable from a new stochastic CRM.

95 There were eight areas where more than one stakeholder provided feedback on possible improvements. There were an additional eight areas where only one stakeholder provided feedback. The most common responses to question 12 were focused on model inputs. While many of these responses were regarding the need for better empirical data on model input values for birds (which was beyond the scope of this project), several were asking for the model to output a summary of the input values used in the model. There were also requests for default values to be provided in the model, but also that users should be able to change these.

96 The second most common comment to question 12, was for a user-friendly approach to modelling. It was clear from other responses that few stakeholders had much experience with using R, and a model

only being available in R could reduce the uptake of the approach among stakeholders. There were also a few appeals for the model to be available as R-code. The next most common response was related to model outputs. There were several recommendations for output summaries, as well as for outputs that provide the error around the estimate and also the probability distribution from the stochastic output.

97 The fourth most common set of recommendations from stakeholders were based around turbine information. Of all the comments provided on turbine inputs or outputs, only one was made by more than one stakeholder. This was in relation to the ability of the Masden (2015) model to use the relationship between wind speed, rotor speed and blade pitch of the turbines. If this element was to be retained in the model, stakeholders expressed a strong preference that default values should be used unless turbine specific parameters are publicly available.

98 A few comments were received about the lack of weather related effects on bird input parameters, though, since the purpose of this project is to create a working stochastic version of the Band (2012) model, this is not within the scope of this project. Similarly, there were a couple of comments regarding avoidance rate data that are used in the model, and this is also not within the scope of this project to address. There were requests for better flexibility in the application of seasonality within the model, though this is relatively easily addressed by users for the point estimates, as predicted collisions are additive, though errors are not.

99 Two comments were also provided regarding the slow speed running the Masden (2015) model, and requests for improved model running speed to be addressed. There were approximately eight different comments that were provided by single stakeholders, which varied greatly. These included comments about the calculations of flux of birds through the wind turbine, use of the oblique approach of birds to the turbine rotor, separate model runs for upwind and downwind flights (which can be done by users anyway) and for model validation.

100 Word cloud analysis (Figure 18) picked up on the multiple recommendations for stakeholders for better bird input values (beyond the scope of this project) and for the model to provide summaries of the model inputs. The requests for different model outputs were also reflected in the word cloud analysis. The word cloud did not pick up on the requests for a user-friendly version of the model, perhaps due to the way that stakeholders described this without using common terms. “Variation” was a relatively common word, which was related to both input values and to outputs. “Speed” was also found relatively frequently, which was related to both model speed, and bird flight speed as a user input.

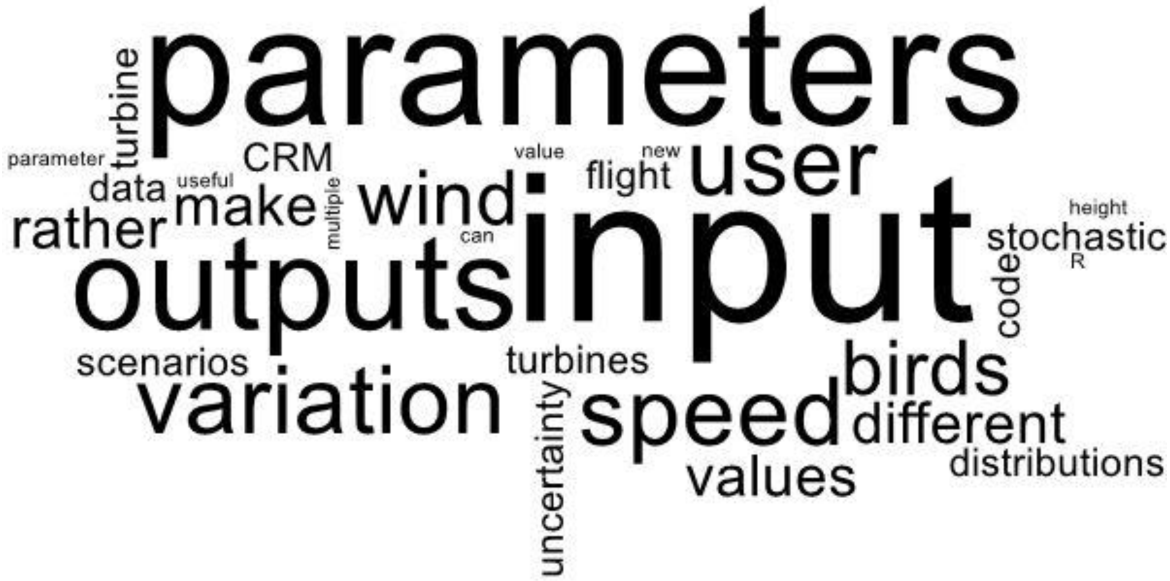

Figure 18 Word cloud of the free text question 12

101 Question 13 was a general free text response question, "Are there any other comments you would like to make about collision risk modelling?", designed as a catch all to ensure that stakeholders were able to provide any other feedback they wished.

102 Responses to question 13 were more variable than other questions, which was expected given the broad question asked. There were few comments made by more than one stakeholder. There were a few comments that the model should be transparent, and related to this a request that the R-code should be freely available. There were also several comments that the CRM is only a model, and there is often both too much precaution used in parameterising it, and too much faith placed in the results, that are often treated as more accurate a prediction than is likely to be true. Other useful comments included a request that single value outputs are no longer used and that only probabilistic outputs are considered, a recommendation is provided for the number of runs needed to produce a useful stochastic output, and that data from the ORJIP project could be used to sense check some of the model calculations. A request was made that care is taken to ensure terms are clear and consistent.

103 There were several other comments that, while useful, were out of scope for this project. These included more use of tracking data to inform bird input parameters, a better understanding of bird aerial density data and more consideration of the difference in weather conditions during surveys with the likely weather conditions when turbines are operational.

104 Word cloud analysis showed that there were many commonly used words (Figure 19), but due to the broad basis for the question there were no key messages that could be better elucidated from the word cloud.

Figure 19 Word cloud from the free text question 13.

3.1.8 Telephone interviews

The telephone interviews were intended to be short (30 – 60 mins) and allow for discussion and exchange of ideas in order to capture any useful additional information. There were four questions:

- Question 1: Did the questionnaire allow you to provide all the feedback you would wish to give? If not, what was missing and what feedback would you want to give?;
- Question 2: When the stochastic CRM is produced do you think you will use it? (If the interviewee is a developer or consultant, then ask: would the new sCRM need to be recommended by the relevant regulator and their SNCB for you to use it?);
- Question 3: Assuming the stochastic CRM is produced and works, what are the next new developments in CRM you would like to see? Are there any other comments you want to make about the survey or CRM for offshore wind farms?; and
- Question 4: How do you think you would implement the results from a stochastic CRM in to an impact assessment and a population model?

105 A total of eight interviews were conducted. Most were with environmental consultants (5), two with developers and one with an NGO. Overall the responses only underlined the comments made in the questionnaire itself.

106 In response to question 1, all of the stakeholders interviewed agreed that the survey was sufficient to allow all the feedback they wished to give. Several provided additional feedback at this stage, with the two most common comments relating to the slow speed of the Masden (2015) model, and the need to provide a user-friendly version as well as a coded version of the model. There were also comments on the value of the outputs including a tabulated summary of the inputs used.

107 Responses to question two all agreed that regulator, and SNCB, approval would be needed to use the model in consent application. However, several consultants noted that they would evaluate the model

anyway and would advise clients accordingly on the value, or otherwise, of the stochastic CRM. One stakeholder noted that the opinion of the RSPB on the model would also have some importance.

108 The most common responses to question three were the need to improve the empirical data on birds used as inputs, and the need to better incorporate information on bird behaviour in relation to weather. There were mixed messages from consultants and developers on the use of the relationship between wind speed, rotor speed and blade pitch. Some consultants noted that they had been provided with these data when asked, while developers noted that under Contracts For Difference ('CFD'), such information would not be readily shared in a public domain, highlighting the need for a generic approach.

109 Responses to question four were the most variable. Issues with the use of a mean and confidence interval around it were noted as problematic for regulators, and that guidance from SNCBs will be needed. One consultant noted that the existing models can give very precise outputs, that is far more than the accuracy of the model, so requested that outputs are always rounded up to the nearest whole bird (at least). Only one stakeholder requested tabular outputs of the collision probability from the model, to be used as an input to a stochastic population model. There were several comments about the CRM and population models being only model, so comparisons being of the most use.

110 Finally, the results of the telephone interviews, while not adding to any stakeholder requested changes to the CRM, did highlight the key messages from the survey.

3.2 Stakeholder requested changes

111 The results of the survey, while taking in to account the scope of the project, results in the following changes that have been requested by stakeholders:

- Create a user-friendly interface for non-R users;
- Speed up the code;
- The number of turbines should be a user input;
- Output predicted collision probability data;
- Provide summary of input values as an output;
- Seasonal (as well as monthly & annual) assessment (default + user defined);
- Error checking inputs and collision probability; and,
- Monthly or seasonal flight height inputs.

4 Comparison of Band (2012) and Masden (2015)

112 The Band CRM is implemented in two distributed forms: a deterministic version in Excel, based on macros and cell-to-cell calculations (Band 2012); and a version with stochastic elements, coded in R (R Core Team, 2016) by Masden (2015).

113 A comparison is presented here, based on general properties and on the outputs when both versions are run for the same scenario. The scenario considered was for a single species (gannet *Morus bassanus*) at a Scottish offshore location. The two implementations will be referred to as the Band and Masden implementations hereafter.

4.1 High level comparison

114 The interfaces to the two models are fundamentally different. The Band implementation is an Excel workbook, with all parameters and data presented cell-wise over numerous spreadsheets. There are effectively no checks on inputs (other than failure to compute), although some elements are protected from alteration. Being a spread-sheet, there is little in the way of an audit trail for presented outputs.

115 Interaction with the Masden implementation is via a main R script file, for high-level parameters, and a series of input files (comma-separated-value: CSV) for data and various parameter sets. Users require an installation of R, appropriate packages and some familiarity with running R code. There are effectively no checks on inputs other than failure to compute i.e. general warnings and errors from R.

116 The data/parameter requirements for the Masden implementation are larger, in keeping with its additional stochastic components e.g. bootstrapped flight heights, parameters governing statistical distributions on CRM parameters. The format of these files, such as column names, must be exactly as expected by the code, so templates need to be followed precisely.

117 Outputs from the Band implementation are tables and graphics within the Excel workbook. Outputs from the Masden implementation are files: CSV for tables and PNG graphics. The input data are also outputted from Masden, giving an audit trail for a particular set of outputs.

118 Calculations using the Band implementation are reasonably fast, on the order of a few seconds to run the imbedded macro for Option 3. However, the spreadsheet requires reconfiguring for each species and speculative turbine configurations. In contrast, the Masden calculations take substantive time. For example, a single species with 1000 Monte-Carlo iterations (a common modest number) might require an hour on a mid-range computer. This scales linearly with the number of species and turbine configurations e.g. two turbine configurations and 10 species might require almost a day of computer time. However, the species-turbine scenarios can be specified in advance, after which the program will iterate over all consecutively.

4.2 Output comparison

119 The principal output from both implementations is the predicted numbers of bird collisions – by month and a yearly total. These are presented for different avoidance rates, large-array corrections, species and "options" for the treatment of bird flight height distributions. The fundamental difference in outputs, is that Masden provides uncertainty in estimates. The uncertainty in collision risk is determined via Monte-Carlo (i.e. resampling of parameter values from statistical distributions on inputs) and expressed by standard deviations, coefficients of variation, inter-quartile ranges, box-plots, etc.

120 The calculations from Band and Masden implementations were compared by using identical inputs for common components and the suppression of Monte-Carlo variability, i.e. the stochastic Masden implementation was forced to provide deterministic predictions for comparability with the Band implementation. This allowed comparison of the basic calculations underpinning both.

121 Using Option 1 (the 'basic' Band model), the risk estimates for the Band and Masden models were deemed to be the same, within mild rounding errors. This indicated that the core functions for collision risk were providing effectively identical results.

122 In contrast, Options 2 & 3 (different treatments for flight height distributions) provided different results, with the Masden collisions estimates being somewhat higher and more consistent with Bands estimates with lower avoidance e.g. Masden's 95% avoidance estimates were similar to Band's 98% avoidance estimates.

123 The difference in results was mainly attributable to an apparent error in the Masden code, whereby the height of the turbine is incorrectly calculated when relating to the bird flight height distributions – effectively lifting the turbine higher. There may be further, more subtle, differences due to the bespoke visual basic 'interpolate' function found in Band, this being implemented differently in Masden.

4.3 Overview

124 Neither implementation is user-friendly, and both are prone to user errors. The current Masden code provides systematically different risk assessments for Option 2 & 3 calculations compared to the Band implementation – which is considered the standard here.

125 The Band implementation benefits from transparency of inputs, but a large, complex interface. There is little to check the validity of inputs, unintended alterations to the spreadsheet are opaque and there is effectively no audit-trail linking inputs to purported outputs.

126 In contrast, the Masden implementation might be considered more direct and efficient in user interaction, but requires interaction with R and is slow to calculate. There is similarly little to check the validity of inputs, but there is a reasonable audit trail linking the code run to the outputs presented. Failure of the code will produce esoteric R errors and would require modest R capabilities to resolve e.g. an error in the input parameter or data files.

5 Coding a new stochastic CRM

5.1 Code review

127 The Masden code was subject to a line-by-line evaluation. Broadly the following was found:

- There is a lack of consistency of coding, suggesting multiple authors, given markedly non-standard approaches.
- The code is inefficient, relying on multiple nested loops for its calculations, rather than vectorised approaches. Related to this, there is a repetition of objects which creates confusion due to synonyms.
- Scoping is poorly conceived in places, where functions rely heavily on global objects.

128 The code benefitted from substantial re-writing for efficiency, consistency and clarity.

5.2 Recoding

129 The Masden code was recoded, with the main goals of improving usability (including speed), transparency and robustness – as well as bug fixes and alterations in light of recent reviews of the code (Trinder 2017 and our detailed code review). These were achieved by creating a user-friendly Graphical User Interface (GUI) to interact with the code and progressively streamlining and improving the structure of the underlying code.

130 The code was moved to a version control system (GIT) and improved in stages. This provides a detailed audit-trail of modifications and reversion to any state is possible. Other developers can collaborate or take over future development relatively seamlessly.

131 There has been vectorisation of many elements to improve speed and readability. Coding consistency has been improved and redundant objects removed. Revised distribution options have been provided for the Monte-Carlo to address the points raised in Trinder 2017.

132 Default parameter values are provided and the inputs are either constrained or flagged to the user if unreasonable. Data can be provided directly through the GUI or from the uploading of template data files. Pop-up help text is provided throughout along with guidance for use.

133 The GUI has been developed in Shiny, a set of R tools that create HTML interfaces to R code. This has many benefits:

- It provides a user-friendly GUI that users access through a standard web-browser – all R code is invisible and no direct code interaction is required;
- It is free and open-source, there is no vendor lock-in;
- The underlying R code is maintained on a remote server that all users connect to. Any alterations are immediately realised for all users. No installation or maintenance of R is required by users; and
- There is a wide-range of ways that input and output can be specified, to suit users.

5.3 GUI implementation

134 General information about Shiny can be found on https://shiny.rstudio.com/. The current version of the GUI can be found at https://dmpstats.shinyapps.io/avian_stochcrm/ and the following gives a brief indication of its use.

135 The workflow is broken into four main steps. In the first instance we set turbine parameters for the wind-farm. The GUI provides sliders and fields for all parameters and plots the implied parameter distribution in each case (Figure 20). Default values are presented and where appropriate field values are constrained e.g. counts are non-negative. In addition, ranges of plausible parameter values were solicited from the Project Steering Group (PSG). Entry of values that are not impossible, but outside expected ranges may elicit warning messages.

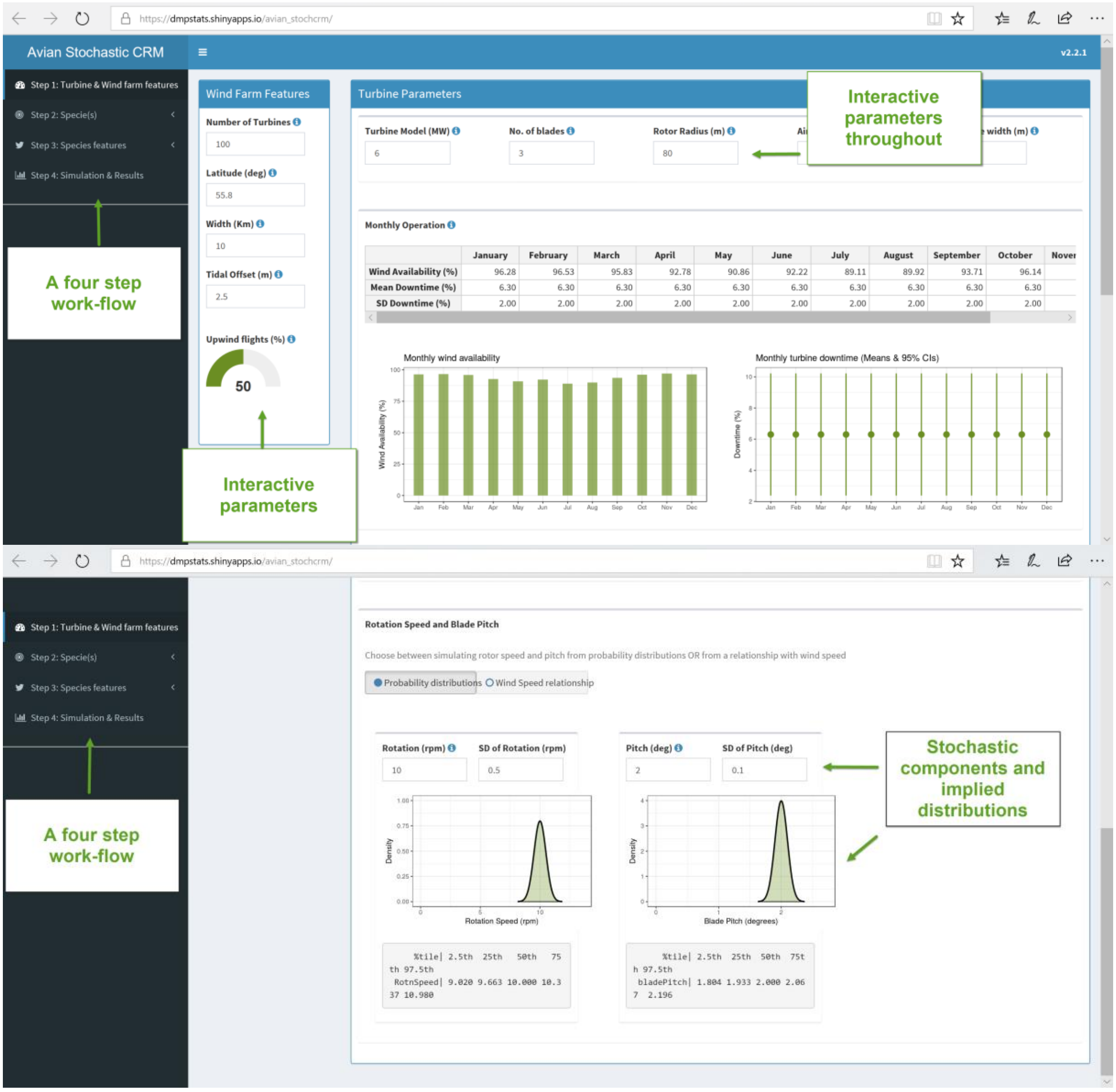

Figure 20 The GUI introduction page. Turbine parameters

136 Additional options have been added for flexibility in portraying relationships between wind-speed and the turbine's rotor pitch and speed.

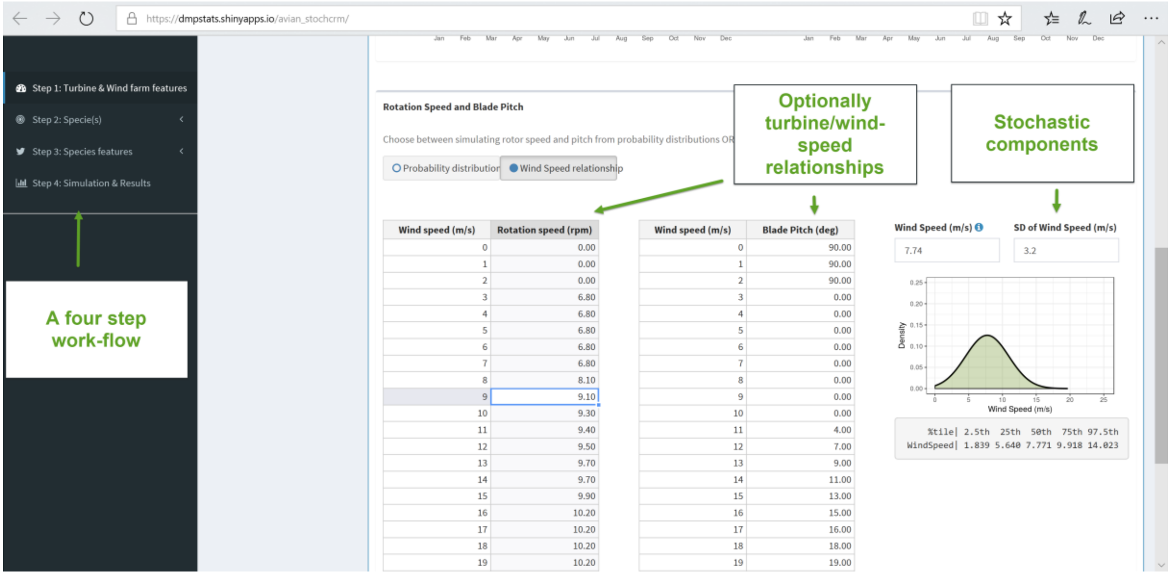

Figure 21 The GUI introduction page. Turbine parameters

137 After setting the turbine parameters, noting there may be several proposed turbine setups (Figure 22), the species of interest are selected. Currently these are pre-defined, as there are limited datasets stored for the flight-height distributions, as described in Masden (2015). Further species can be added if equivalent data is available.

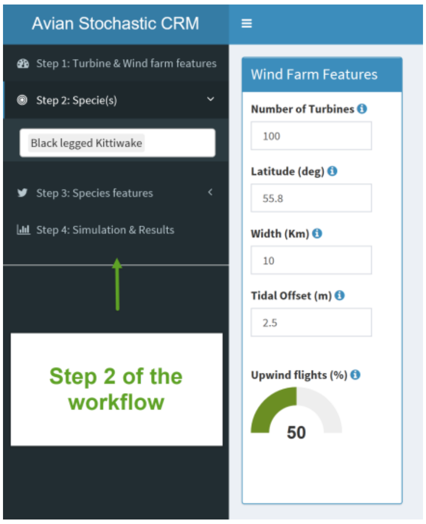

Figure 22 There are four basic steps – defining turbine parameters, species to consider, species parameters, then the size of simulation, before results.

138 Each of the species have parameter sets that are defined (Figure 23). As before, parameters for the stochastic components are set and the implied distributions are plotted. Entries are constrained to avoid impossible values and offers warnings if entered values are outside expectations, as per the PSG opinions.

139 A number of modifications have been made with respect to bird densities and their stochastic treatment, in line with the findings of the review by Trinder (2017). The previous default treatment by truncated Normal is retained, but with the upper truncation value removed. Further, users may offer an estimate and confidence bounds or a general series of reference points for whatever distribution they think applies.

140 Bird flight height distributions similarly have a range of options: a single flight height distribution as previously held in the Masden code, or one of the user's choosing; alternatively, bootstrap flight height distributions as previously held in the Masden code, or a set of the user's choosing. Templates can be downloaded from the app to ensure conformity of input data when uploaded.

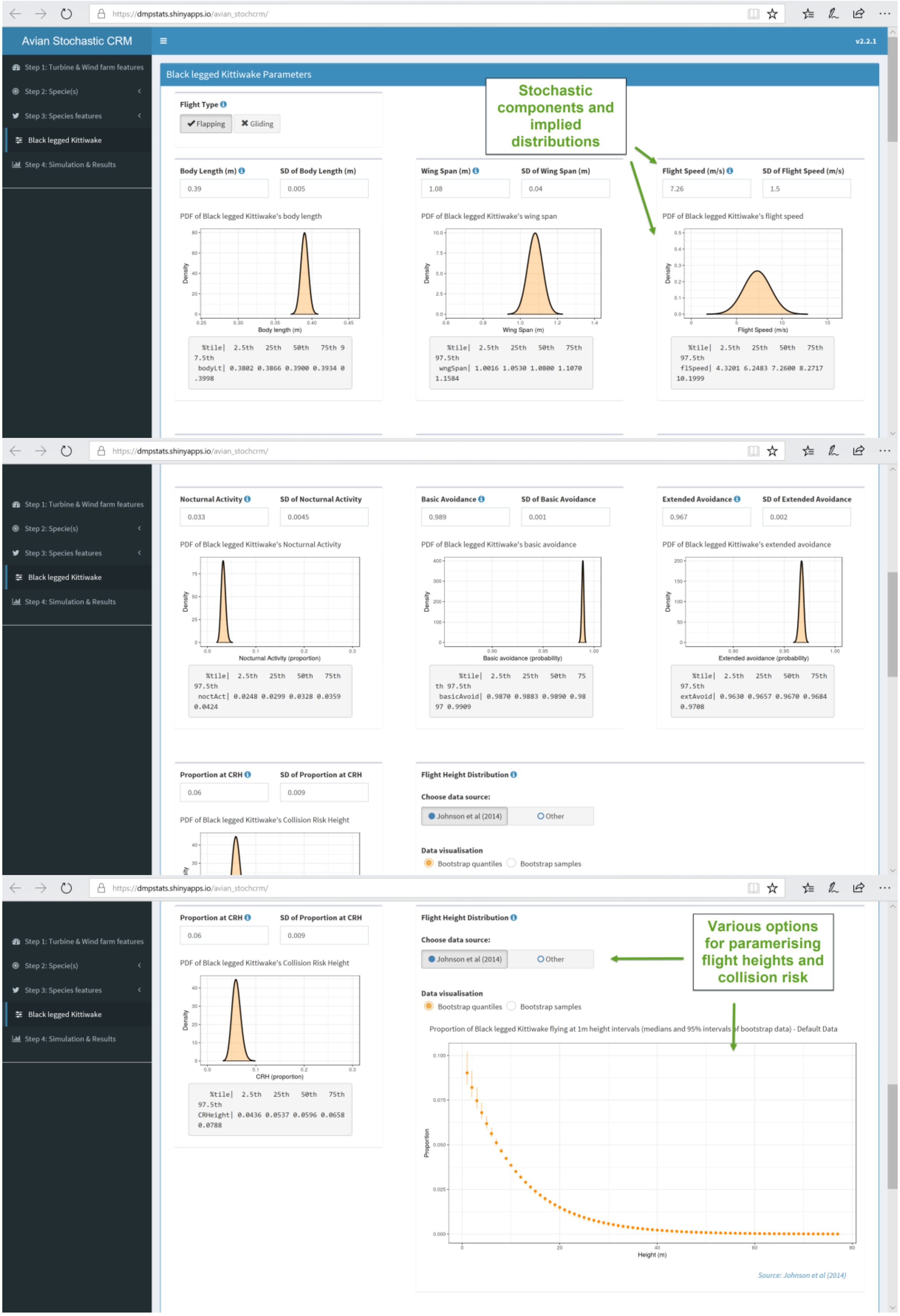

Figure 23 The interface is similar throughout – interactive parameter setting then a graphic showing what is implied.

141 The simulation is set in motion – the amount of time required being proportional to the number of turbines, species and simulation iterations (Figure 24).

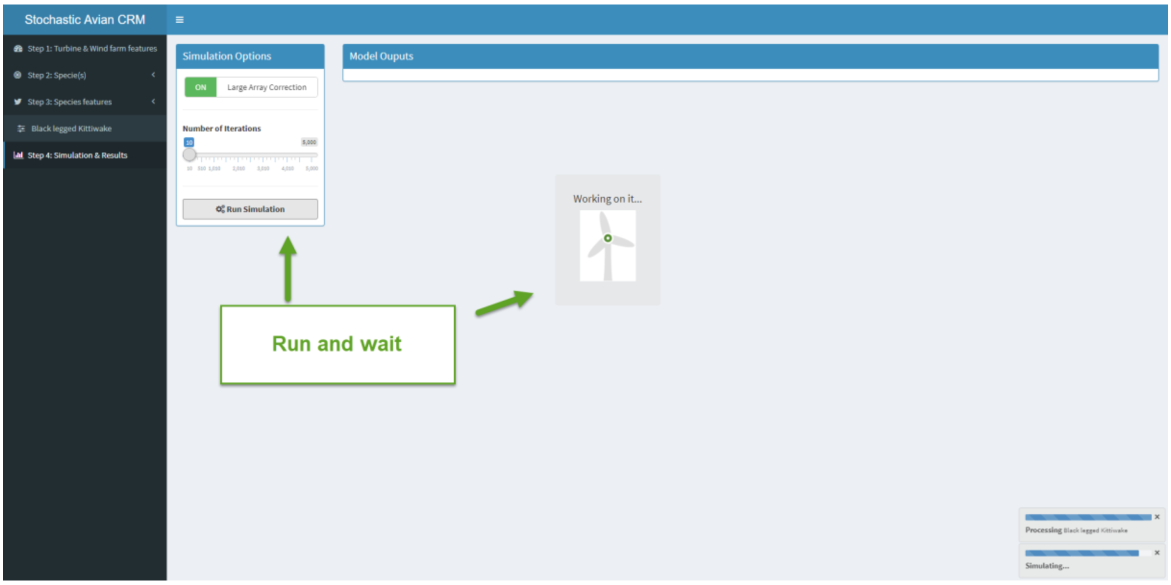

Figure 24 The final step is setting the number of iterations and large-scale corrections.

142 Outputs are extensions of those of Masden, albeit rendered in HTML and available as downloads (Figure 25).

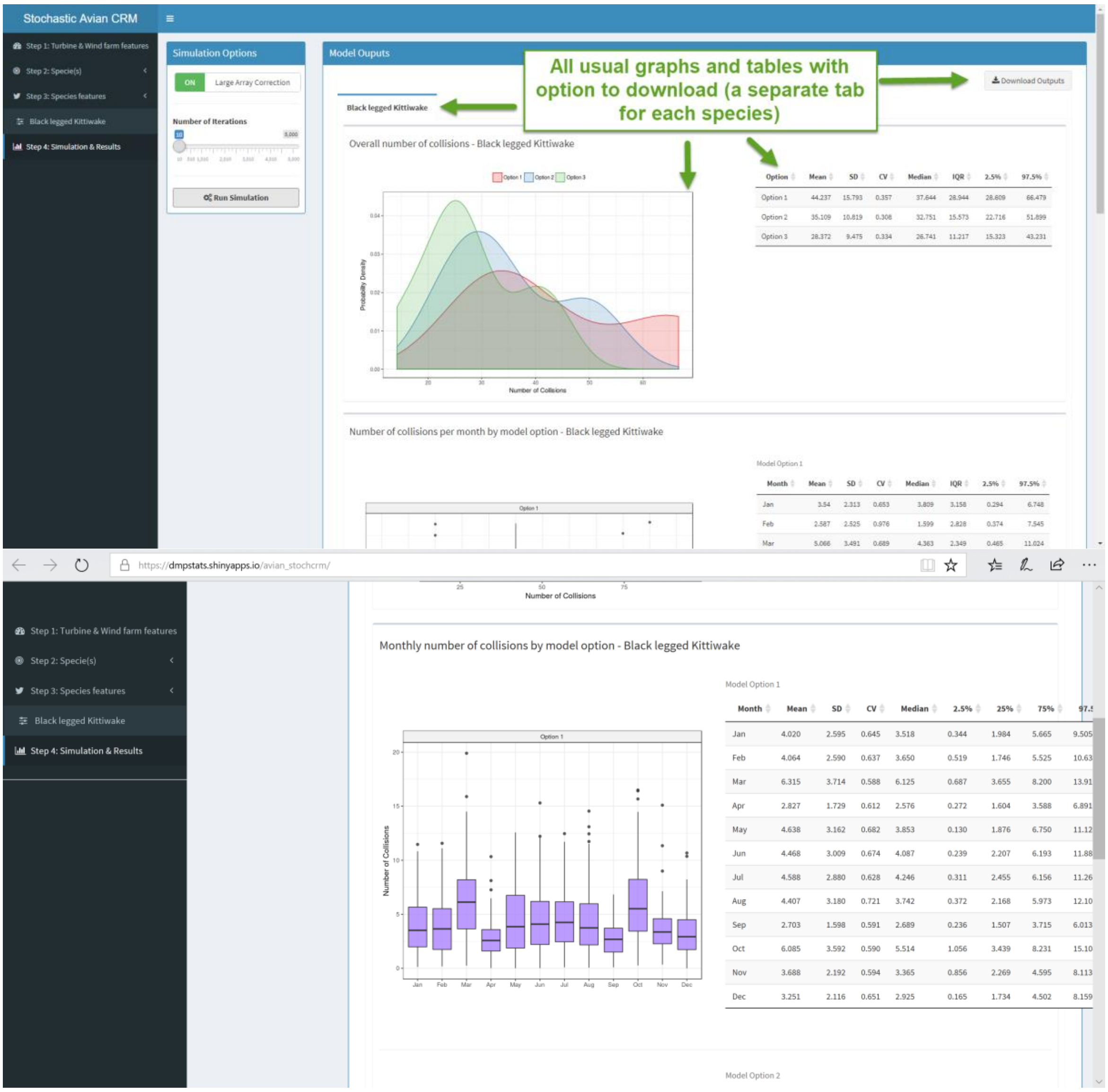

Figure 25 The results are tables and plots similar to those in Masden, rendered in the GUI. There are download options.

6 Testing of new stochastic CRM code

143 The new code was tested by its conformity with Masden 2015 outputs and the point estimates of Band 2012. Where disagreement was found between Masden and Band, the Band results were assumed correct and the new CRM code conforms to this.

144 The GUI was further tested by the presentation of extreme and corrupt inputs (including data-files) to ensure sensible behaviour.

7 Conclusions

146 To address the identified need for improved modelling of stochastic variation in collision risk modelling of seabirds for offshore wind farm development applications a stakeholder survey was used to inform the changes needed to create a new stochastic CRM.

147 The stakeholder survey identified seven key changes needed to the currently available CRMs. These included a user-friendly interface, full data outputs, seasonal inputs and assessments, error checking and flexibility for users to change default values.

148 These changes were implemented by experienced R-code developers through the updating and streamlining of the existing Masden (2015) code. The key changes requested by stakeholders were implemented, along with the recommendations of Trinder (2017).

149 A user-friendly interface was developed by coding these models into a Shiny app in R (app version 2.2.1 at time of reporting found at https://dmpstats.shinyapps.io/avian_stochcrm/) that allowed users to easily input values for turbines and birds and incorporated default values and guidance to reduce human error. Flexibility was maintained by allowing users to use non-default values.

150 There are two variants of the revised stochastic CRM, both coded in R. Both provide the full GUI interface via shiny as outlined. The online version runs on the Shiny server, while a downloadable version will run locally on the computer it is installed on, using the internet browser on that computer. It can be downloaded from https://github.com/dmpstats/stochCRM.

151 Data outputs from the Shiny are provided both graphically and as a data download. This provides end users with all the information needed to interpret the collision risk values, and their uncertainty.

152 Both the R-code variants of the sCRM are a highly flexible, stochastic model that provides a prediction of seabird collisions with a correctly calculated error estimate for use in Environmental Impact Assessments.

8 Contributions and Acknowledgements

The project was managed by Dr Ross McGregor (HiDef Aerial Surveying), who also produced and analysed the questionnaire with Sue King (Sue King Consulting). The CRM shiny app and R code were produced by Dr Carl Donovan (DMP Statistical Solutions) and Dr Bruno Caneco (DMP Statistical Solutions). The project was overseen by Andy Webb (HiDef Aerial Surveying).

The authors would like to thank all of those stakeholders who provided a response to the questionnaire, and to those who also agreed to follow up telephone interview. The high response rate to the requests for feedback was greatly appreciated.

The invaluable input to the entire project process from the Project Steering Group greatly aided in the success of this project. The Project Steering Group comprised: Jared Wilson (Marine Scotland Science), Helen Wade (SNH), Julie Black (JNCC), Aly McCluskie (RSPB) and Mel Kershaw (Natural England).

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Appendix I Questionnaire *Pro Forma*

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An improved stochastic Collision Risk Model for seabirds in flight

Stakeholder Questionnaire

1 OF 11

1 Introduction

1 Collision Risk Models (CRM) are used to predict the number of birds that may collide with wind turbines. This project will develop an improved stochastic CRM for seabirds by consulting with stakeholders to determine their requirements and then develop CRM software to meet those needs.

2 Phase one of this project is to identify existing gaps in the CRM process through stakeholder engagement. This questionnaire asks 13 questions in 8 sections covering each part of the CRM process. There are free text boxes at the end of the questionnaire, where you can provide feedback on which improvements you think would be most important and any other feedback you may wish to give to the project delivery team. Please share this questionnaire with any other individuals in your organisation that may wish to respond. We would prefer one response per individual, rather than per organisation.

3 The overall aim of this project is to produce a user-friendly CRM that uses the variability in the input values to produce an output that gives a range of output values around some central point (mean, median). The CRM will be coded in 'R', providing a great deal of flexibility to users. However, this is not friendly to all users, so a graphic interface (https://shiny.rstudio.com/) could be produced if stakeholders considered it useful. The CRM would be tested against the original Band (2012) model, to ensure that it provided the same calculations, but with the added advantage of variability in input values being able to produce an output with suitable and useable variability.

4 This questionnaire does not ask any questions about the bird input parameters. It is intended that the improved stochastic CRM will provide default values based on the species selected, but these will also be user definable.

5 The questionnaire specifically asks for feedback on turbine input values and the usefulness of these. Many of the input parameters may require both a mean value and the standard deviation around that mean. Feedback is sought on both the input values themselves and the standard deviations around them. The input values required from the Masden (2014) stochastic CRM are:

- Number of turbine blades;
- Turbine rotation speed (r.p.m.) – this is the speed the turbine will operate at most often;
- Turbine rotor radius – measured from the axis of rotation to blade tip, not just the blade length;
- Turbine hub height – Sum of the rotor radius and minimum blade clearance above Highest Astronomical Tide (HAT);
- Maximum blade chord width;
- Blade pitch – in degrees relative to rotor plane; and,

- Turbine operation time – this needs to be provided by month, and is the combination of predicted time spent operation from the predicted wind resource, and the planned and emergency maintenance down time.

In addition, the Masden (2014) stochastic CRM requires inputs on the relationship between wind speed (ms^{-1}), rotor speed (rpm) and blade pitch (degrees).

6 The Masden (2014) CRM also provides tabular and figure outputs. These are:

TABLES

1. Overall summary table of collisions by species, turbine and model option. Results are presented as monthly mean, standard deviation (SD) and coefficient of variation (CV), and median and inter quartile range (IQR).
2. Monthly summaries of collisions. Separate tables are produced according to species, turbine and model option for example 6_Black_legged_Kittiwake_monthlySummaryOpt3.csv. Results are presented as mean, standard deviation (SD) and coefficient of variation (CV), and median and inter quartile range (IQR).
3. Summary of sampled bird parameters by species, turbine and model option presented as mean and standard deviation (SD), and median and inter quartile range (IQR).
4. Summary of sampled turbine parameters by species, turbine and model option presented as mean and standard deviation (SD), and median and inter quartile range (IQR).

FIGURES

1. 3-panel boxplots of monthly collisions for model options 1, 2 and 3 by species, and turbine type.
2. Density plots of numbers of collisions by species, and turbine type. A density curve is plotted for each of the 3 model options.
3. If 2 or more turbine models are included, then a 3-panel figure will be produced for each species, with the panels representing model options 1, 2 and 3 and each panel containing density plots for the different turbines included.

7 To ensure that we fully capture the existing issues stakeholders have with the existing CRMs (i.e. Band 2012 and Masden 2014) a selection of stakeholders will be invited to participate in a short telephone interview.

8 Once completed the survey should be returned to ross.mcgregor@hidefsurveying.co.uk

2 Questionnaire

2.1 Personal information

Name	
Organisation	

2.2 CRM Concept

Question 1. Do you think that CRM is a useful method for assessing potential impacts from offshore wind farms?		
Yes	☐	If Yes, please describe the benefits of CRM. If No, please describe why you think that CRM is not a useful method.
No	☐	
Don't know	☐	

2.3 Experience

Question 2. How would you describe your experience in using the Band (2012) CRM for offshore wind farms? (Please select *all* that apply to your current *and* past use of the Band (2012) CRM).			
Model user Please tick if your primary role is using the Band (2012) CRM.	☐	Expert Experienced using the Band (2012) CRM in Excel in relation to consent applications	☐
		Occasional Have occasionally used the Band (2012) CRM for technical reporting, or undertaken QA of work done by others	☐
		Basic Have used the Band (2012) CRM once or twice, but never in relation to technical reporting or consent applications	☐
		None Have never used the Band (2012) CRM	☐
Model output interpretation Please tick if your primary role is interpreting the output from the Band (2012) CRM.	☐	Supervisory Supervise others in the use of Band (2012) CRM.	☐
		Reviewer Reviewed others use of Band (2012) CRM.	☐
		Other Please describe your use of the Band (2012) CRM in the box below	☐
		If other, please describe your use of the Band (2012) CRM)	

Question 3. What level of R user do you consider yourself to be?		
Expert	☐	If other, please describe your experience with R
Regular	☐	
Occasional	☐	
Never	☐	
Other	☐	

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Question 4. Have you ever used the Masden (2014) stochastic CRM (or another stochastic CRM) in R?		
Yes (Masden (2014) CRM) (if yes, please go to Q.5)	☐	If you have used another sCRM, or selected other, please describe your use of a stochastic CRM here.
Yes (Other stochastic CRM)	☐	
No (if no please go to Q.6)	☐	
Other	☐	

Question 5. Have you ever experienced issues running the Masden (2014) stochastic CRM (or another stochastic CRM) in R?		
Yes.	☐	If yes, what problems have you experienced and can you suggest any solutions to these problems?
No	☐	
Don't know	☐	

2.4 CRM Inputs

Bird parameters

Question 6. Are there any input values for birds (e.g. wind span, length, flight speed, nocturnal activity) that you think should be changed, improved or added?		
Yes.	☐	If yes, please describe which values should be changed or improved and why.
No	☐	
Don't know	☐	

Question 7. Should the new stochastic CRM retain all of the model Options (1, 2, 3 & 4) described by Band (2012)?		
Yes	☐	In no, please describe why and what changes you would like to see to the modelling of the different options.
No	☐	
Don't know	☐	

Turbine parameters

Question 8. The Masden (2014) CRM includes the relationship between wind speed, rotor speed and blade pitch. Given the commercial sensitivity of this information, should a precautionary generic approach be used or should turbine specific data used for consent applications?		
Precautionary generic approach.	☐	Please explain why you gave this response.
Turbine specific approach	☐	
Other	☐	
Don't know	☐	

2.5 CRM Operation

Question 9. Do you think that the Band (2012) model (& Masden (2014) model) correctly calculates the probability of collision BEFORE avoidance rates are applied?		
Yes	☐	If no, please describe why you think that the current model does not make the correct calculation.
No	☐	
Don't know	☐	

2.6 CRM Outputs

Question 10. Are there any outputs from the Masden (2014) model not currently provided that may be useful to include in a future model? (A description of the outputs is provided in paragraph 6 of the introduction).		
Yes	☐	If yes, please describe the additional outputs that would be useful.
No	☐	
Don't know	☐	

2.7 CRM error checking

Question 11. The current Band (2012) and Masden (2014) models do not provide any error checking. Is there any turbine specific error checking that would be useful to include in an updated Stochastic CRM?		
Yes	☐	If yes, please provide any examples of useful error checking.
No	☐	
Don't know	☐	

2.8 CRM improvements

Question 12. What would be the main improvements you would like to see to a stochastic CRM? Please provide your order of preference/importance (highest first).

Question 13. Are there any other comments you would like to make about collision risk modelling?

THANK YOU FOR COMPLETING THE SURVEY.

3 References

Band, W. 2012. Using a collision risk model to assess bird collision risks for offshore windfarms. Report to The Crown Estate (Strategic Ornithological Support Services); Project SOSS-02. British Trust for Ornithology, Thetford, UK.

Masden, E. 2014. Developing an avian collision risk model to incorporate variability and uncertainty. NERC.

Appendix II Telephone survey *Pro Forma*

MS Stochastic CRM stakeholder survey - follow up interview questions

Name	**Organisation**
Date	**Time**
Form of interview (e.g. phone, in person, via email, etc.	
Ask the interviewee if they have completed the survey questionnaire. **Yes** ☐ **No** ☐ If the interviewee has not completed the survey, walk them through the questions and record the answers for them.	

Question 1: Did the questionnaire allow you to provide all the feedback you would wish to give? If not, what was missing and what feedback would you want to give?

Question 2: When the stochastic CRM is produced do you think you will use it? (If the interviewee is a developer or consultant, then ask: would the new sCRM need to be recommended by the relevant regulator and their SNCB for you to use it?)

Question 3: Assuming the stochastic CRM is produced and works, what are the next new developments in CRM you would like to see? Are there any other comments you want to make about the survey or CRM for offshore wind farm?

Question 4: How do you think you would implement the results from a stochastic CRM in to an impact assessment and a population model?

Thank the interviewee for their time.