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## Stochastic Band CRM – GUI User manual

Draft V1.0

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Draft V1.0

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# 1 Overview

This document provides guidance on use of the Graphical User Interface (GUI) developed for the stochastic Collision Risk Model (CRM) created by Masden (2015a,b) – itself based on the deterministic models of Band (2012).

Masden’s program was presented as R code (R Core Team, 2016), which users would interact with via standard R command-line. This code has been ported to Shiny (<http://shiny.rstudio.com/>), which is also in R, but offers a user-friendly GUI accessible via standard web-browsers. The advantages are manifold:

- Users are not required to use any R code.
- Users are not required to install or maintain R – their web-browser will communicate with remote servers that carry the necessary software and conduct the calculations.
- Updates are made directly to the server, so are immediately propagated to users.

The core calculations are largely the same as for Masden’s code, so associated documentation applies here. The core deterministic calculations underpinning the Masden code (i.e. without stochasticity) follow that of Band (2012), so the associated documentation there is also relevant.

Some core alterations and additions have been made for the GUI, in particular to address deficiencies identified in the review by Trinder (2017). In addition, there are correction of some bugs and general improvements in structure, speed and efficiency.

The use of the GUI, hereafter the *app* or *shiny-CRM*, will be demonstrated by means of an example set of risk calculations that mirror that presented by Masden (2015c), being the user manual for the use of their command-line stochastic CRM.

## 2 Accessing the Shiny-CRM

The Shiny-CRM is hosted on the Shiny servers of RStudio. Access is via a web-browser and is known to work with common types e.g. Chrome, Firefox or Explorer. To access the GUI, use the following link:

[https://dmpstats.shinyapps.io/avian\\_stochcrm/](https://dmpstats.shinyapps.io/avian_stochcrm/)

No special software beyond a common browser is required. Being cloud-based, performance will be affected by very poor internet connections. However, standard broad-band speeds should provide reasonable performance. Currently, 20 users should be able to access the app simultaneously without detriment. Note, currently long periods of inactivity may lead to disconnection.

Following the link should present the user with an opening screen similar to Figure 1. This is the specification page for the windfarm – effectively turbines and wind properties. This is the first of four stages in the usual workflow, indicated on the left-hand menu. The workflow menu will provide different pages for input-output.

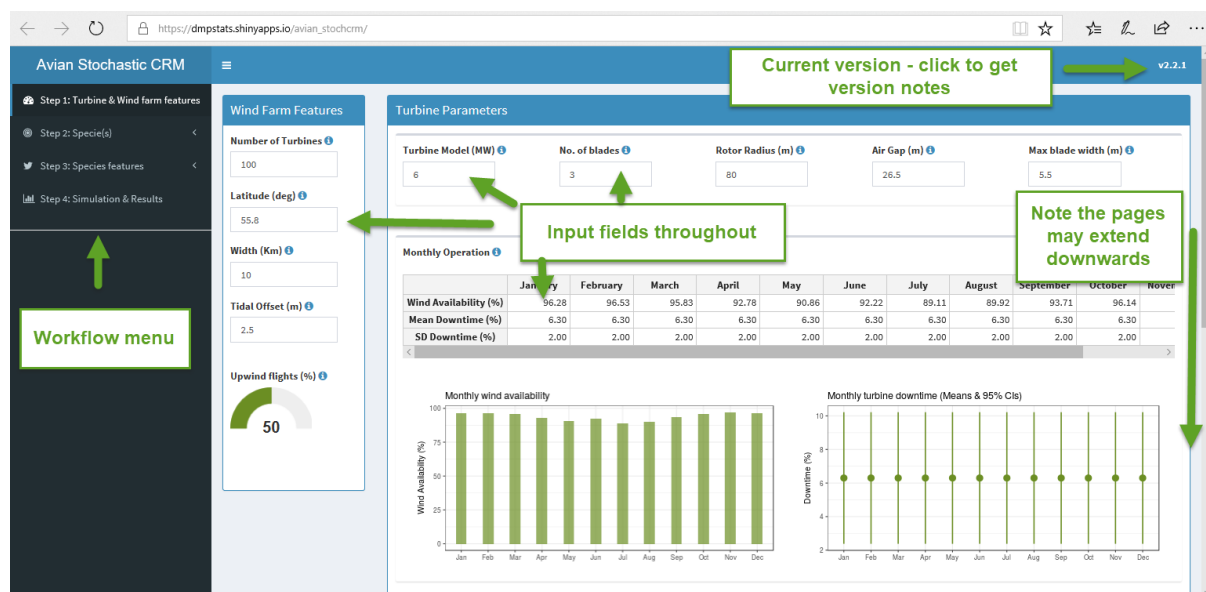


Figure 1: Shiny-CRM front page

Use is intuitive, with the majority of inputs being through editable fields. In terms of general features (Figure 2 to Figure 4):

- There are pop-up help boxes for each input
- There is version change information
- The side-bar is collapsible
- Warnings and errors may appear on the left for odd or impossible values

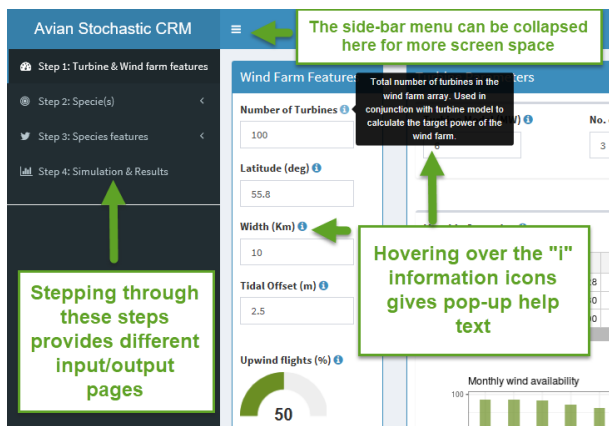


Figure 2: General app use

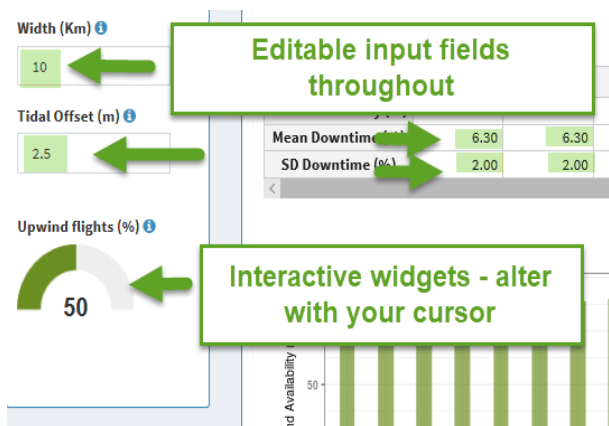


Figure 3: General app use

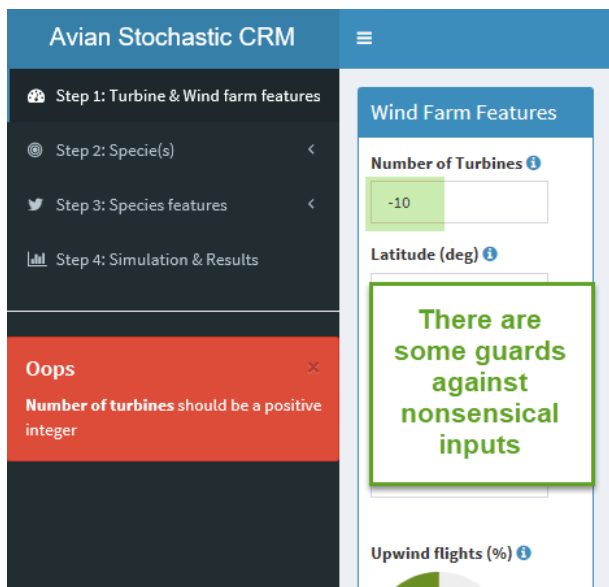


Figure 4: General app use

### 3 Data requirements for the Shiny-CRM

The shiny-CRM offers a user-friendly interface to a modified version of the Masden R command-line CRM. The running of the CRM simulations requires a number of parameter settings from the user, mainly to define:

- The nature of the windfarm in terms of turbine properties and wind.
- The relevant parameters for the bird species under assessment.

The turbine parameters are relatively few in number and can be reasonably entered into the fields of the GUI. The inputs/parameters required for a bird species are relatively voluminous and required for each species. Specifically, we require estimates with uncertainty for:

- Biometric & flight data
- Monthly density data
- Modelled flight height distributions (possibly bootstrapped to reflect uncertainty)

In particular, flight distribution inputs can be voluminous, being expressed as the distribution over a height range of 300m at 1m intervals. The bootstrap approach as currently encoded, further requires 200 such inputs per species.

In keeping with Masden, the above inputs are already contained within the software for the following 12 species, although editable:

Species
Fulmar ( <i>Fulmarus glacialis</i> )
Gannet ( <i>Morus bassanus</i> )
Lesser Black-backed Gull ( <i>Larus fuscus</i> )
Herring Gull ( <i>Larus argentatus</i> )
Great Black-backed Gull ( <i>Larus marinus</i> )
Black-legged Kittiwake ( <i>Rissa tridactyla</i> )
Guillemot ( <i>Uria aalge</i> )
Razorbill ( <i>Alca torda</i> )
Little Auk ( <i>Alle alle</i> )
Puffin ( <i>Fratercula arctica</i> )
Arctic skua ( <i>Stercorarius parasiticus</i> )
Great skua ( <i>Stercorarius skua</i> )



## 4 Demonstration of use

The example used here follows that of Masden (2015c). This was a fictitious example for a wind farm planned in the North Sea with the following properties:

- The planned wind-farm has a width of 10 km and projected output of 600MW.
- The proposed location is at 55.8 degrees North (longitude being irrelevant for the calculations).
- The tidal offset is 2.5 metres.
- Only one species is considered: the black-legged kittiwake (*Rissa tridactyla*).

### 4.1 Step 1: Windfarm/turbine and wind specification

The following mirrors the specification in Masden's example, starting with the windfarm characteristics, comprising 4 main parts (Figure 5):

1. Wind farm "features"
2. Turbine characteristics
3. The wind characteristics
4. The turbine speed/pitch and wind speed

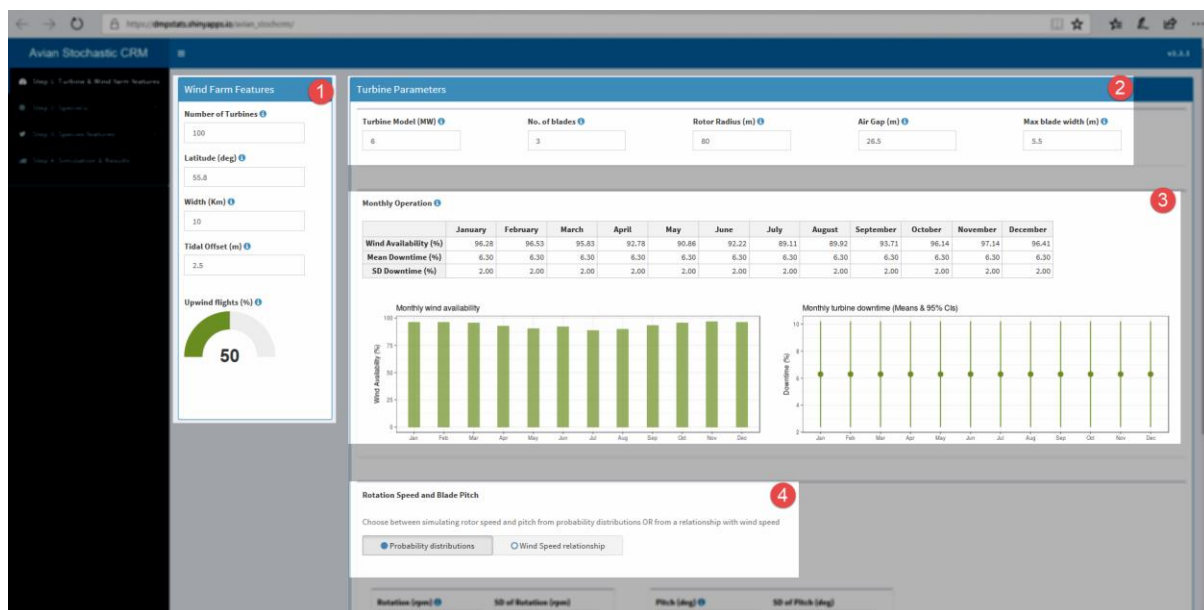


Figure 5: main areas of interaction for the wind-farm properties

We look at each in detail.

### 4.1.1 Wind farm features

First, we look to the Wind Farm Features box (Figure 6).

- The total power of the wind-farm is to be 600MW, noting a modification requested by users was that the number of turbines be a specification. Hence, here we select 100 turbines (later set to 6MW) to achieve the total power.
- Width is set to 10km, the proportion of bird flights up/downwind to be 50%
- The latitude of the wind farm is set to 55.8 decimal degrees (noting this is required to calculate day length).
- The tidal offset is set to 2.5 metres

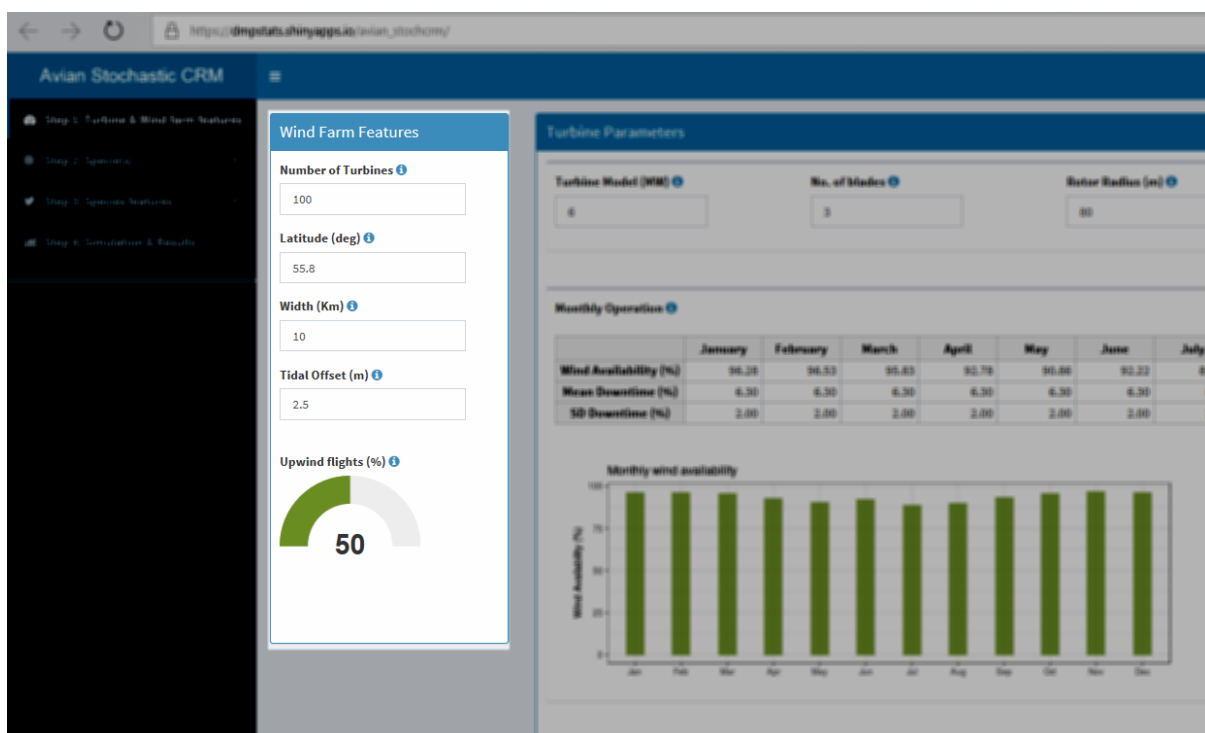


Figure 6: Wind farm features box

## 4.1.2 Turbine parameters relating to an individual turbine

All turbines are assumed to be broadly the same. We specify their (Figure 7):

- Power – here 6MW (giving the wind-farm 600MW maximum)
- Number of blades – here 3.
- Rotor radius – here 80m
- Air gap<sup>1</sup> – 26.5m
- Maximum width<sup>2</sup> – here 5.5m

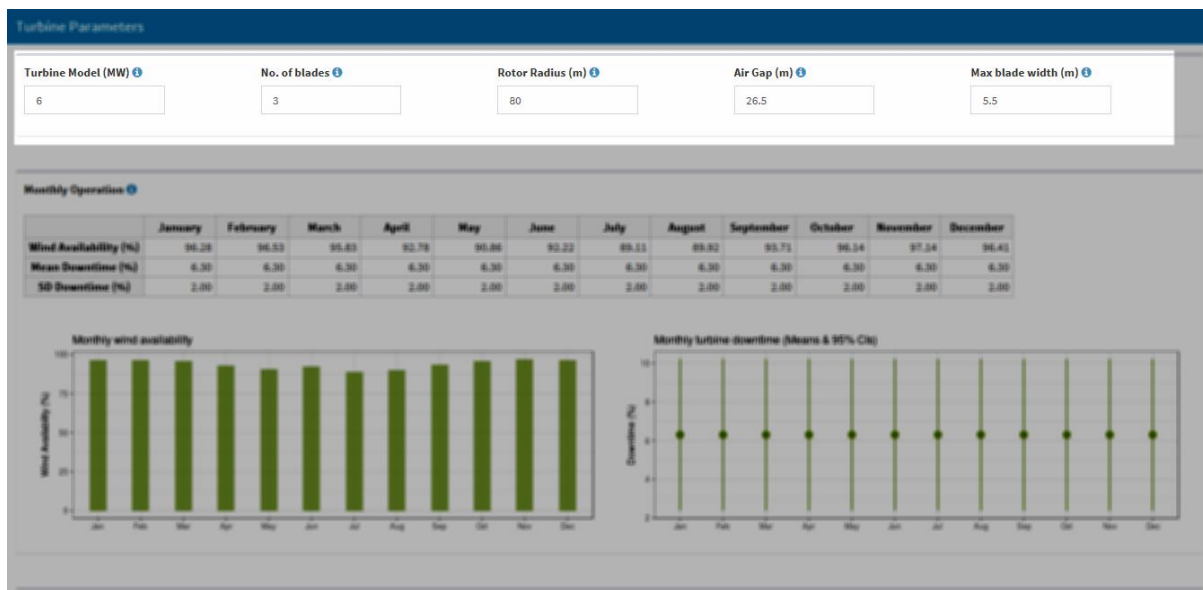


Figure 7: individual turbine features

<sup>1</sup> “Air gap” here equates to the parameter Hub height from the Masden code – thought to be confusing terminology by stake-holders.

<sup>2</sup> An uncertainty measure was given in Masden (an SD of 0.n3 in this example). This was dropped in after discussion.

### 4.1.3 Operational time – wind availability and maintenance schedules

The amount of wind and operational time throughout the year is required on a monthly basis. In particular, monthly estimates of:

- %-age of time wind is availability (no uncertainty specified)
- %-age of time required for maintenance downtime, with uncertainty (standard deviation)

The example figures of Masden are used here (Table 1), entered into the Monthly Operation fields (Figure 8), which the app will display graphically (Figure 9).

Table 1: Masden's example operational figures

Month	Wind availability	Mean maintenance	SD maintenance
Jan	96.28	6.3	2
Feb	96.53	6.3	2
Mar	95.83	6.3	2
Apr	92.78	6.3	2
May	90.86	6.3	2
Jun	92.22	6.3	2
Jul	89.11	6.3	2
Aug	89.92	6.3	2
Sep	93.71	6.3	2
Oct	96.14	6.3	2
Nov	97.14	6.3	2
Dec	96.41	6.3	2

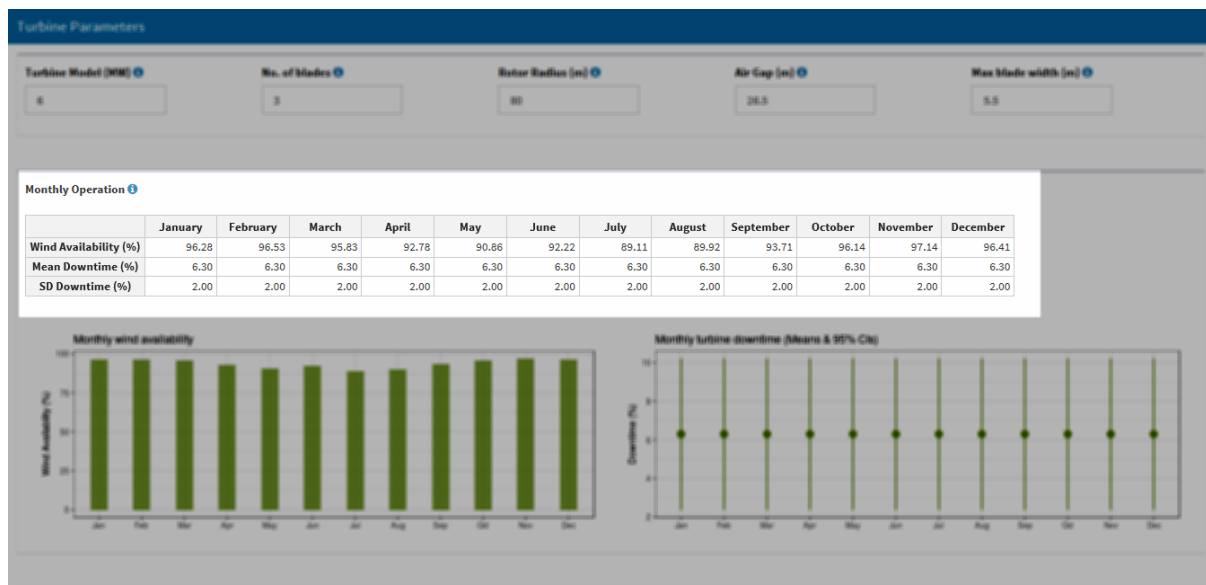


Figure 8: Wind availability and downtime

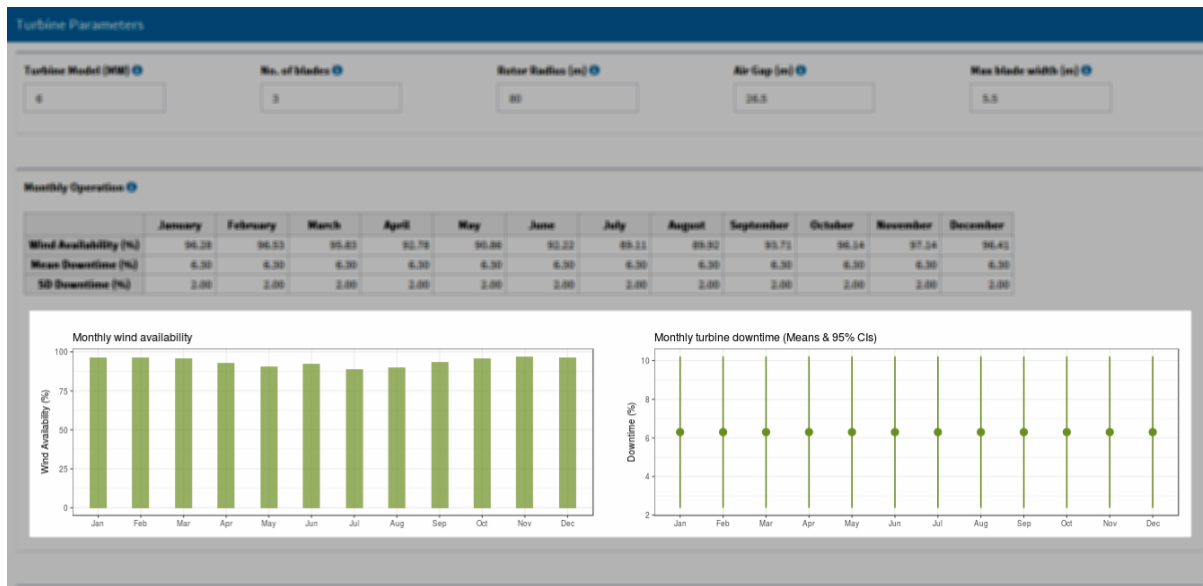


Figure 9: Wind availability and downtime

Note, under the Masden command-line version, this information would be provided via text files (Comma Separated Values – CSV) conforming strictly to the row and column naming conventions.

#### 4.1.4 Wind and rotors

Under the original Masden command-line version, a relationship was to be specified between wind speed and the rotor speed and pitch<sup>3</sup>. This was deemed to be difficult to fulfil, as these details may be commercially sensitive and unlikely to be provisioned by manufacturers. As such, two approaches are provided here:

1. Details of the relationship between rotor speed, pitch and wind-speed (wind speed treated as a stochastic element, with mean and standard deviation parameterising a truncated Normal distribution). This is presented in Figure 10.
2. Rotor speed and pitch only specified, with estimates and uncertainty (i.e. mean and standard deviation). This option is shown in Figure 11.

It is thought in practice that the second option will be used, due to commercial sensitivities. However, in keeping with the original Masden example, the rotor speed/pitch and wind relationships are used for calculations here. Wind is specified as a mean of 7.74 m/s (SD of 3.2).

<sup>3</sup> Parameters existed for stochastic treatment of the rotor speed and pitch, but were set to zero to accommodate the rotor speed/pitch to wind relationships.

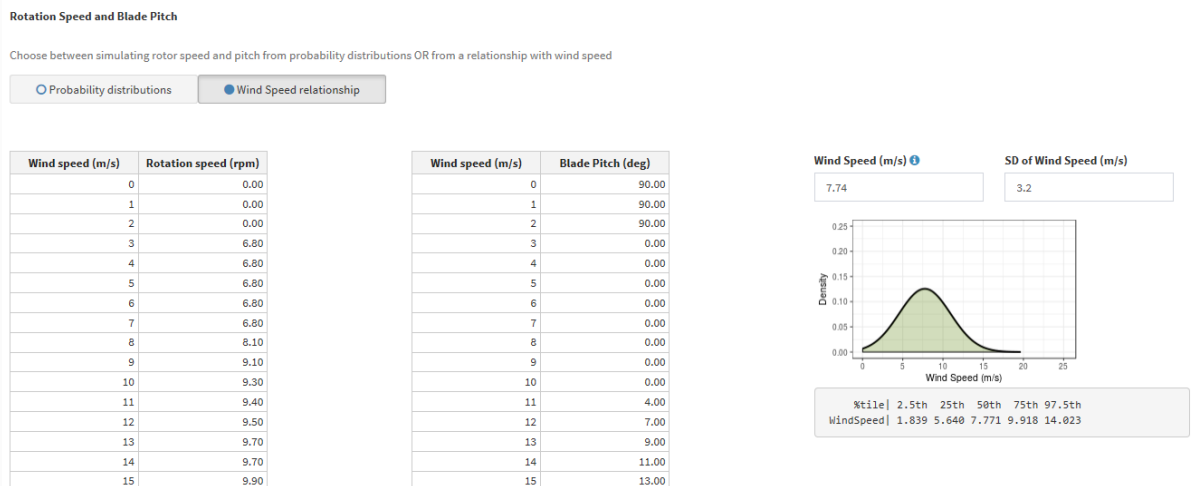
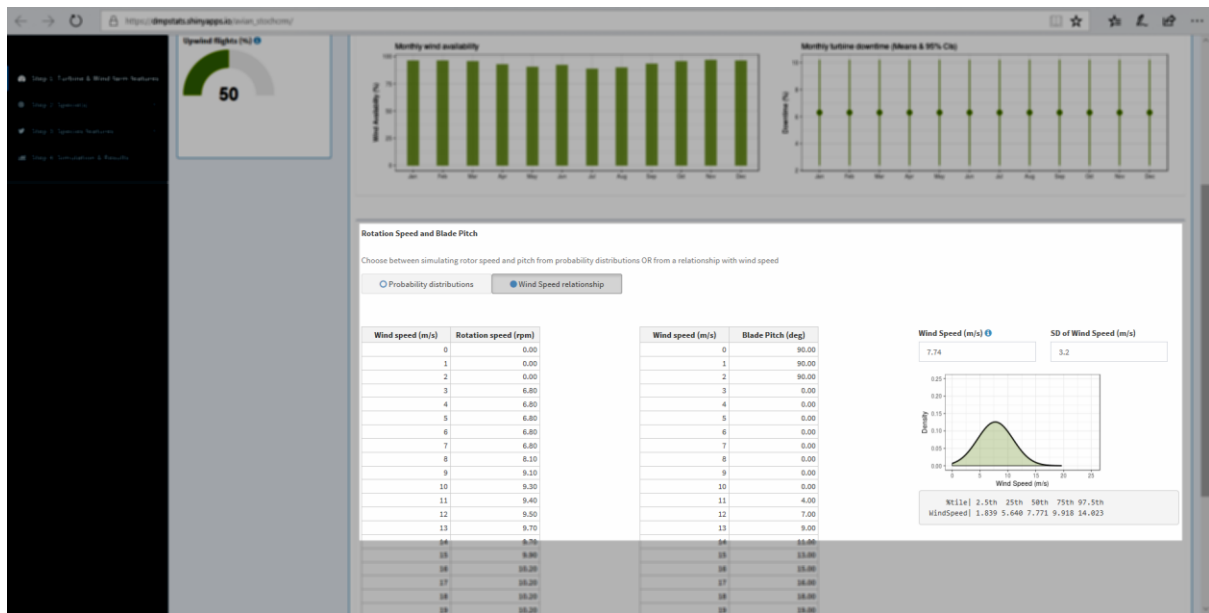


Figure 10: rotor speed/pitch and wind relationships

Under the command-line code version, these relationships are provided through a data file (CSV) with strict naming conventions for both the file and contents<sup>4</sup>.

<sup>4</sup> The “wind\_X.csv” file, where X is the turbine power.

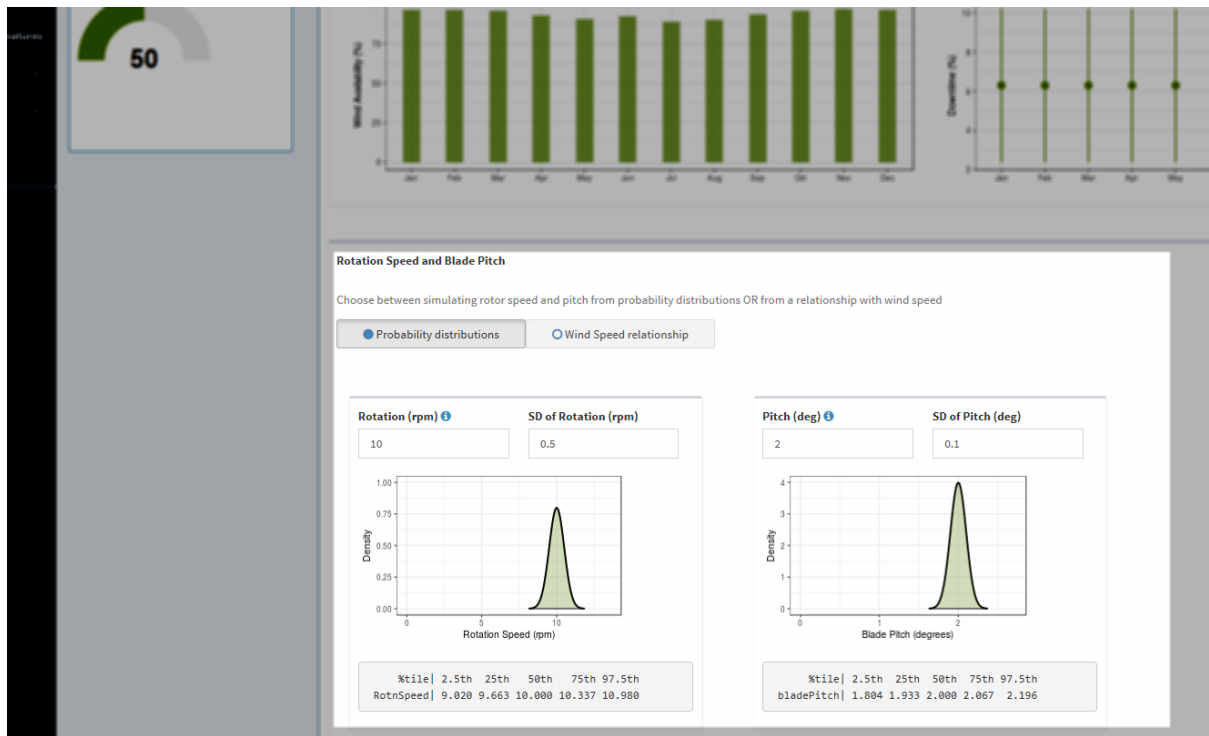


Figure 11: Stochastic rotor speed and pitch.

## 4.2 Step 2: Species selections

As indicated previously, data requirements at the species level can be voluminous and several species have data stored within the app. The species of interested are selected from the drop-down menu, which will populate the required fields (Figure 12). The fields are subsequently editable and will offer guidance about plausibility of values.

The screenshot displays the 'Avian Stochastic CRM' interface. On the left, a sidebar shows 'Step 1: Turbine & Wind farm features' and 'Step 2: Specie(s)'. The 'Step 2: Specie(s)' section is active, showing a list of species: Black legged Kittiwake, Arctic Skua, Arctic Tern, Atlantic Puffin, Black headed Gull, Black throated Diver, Common Guillemot, Common Gull, and Common Scaup. Two green arrows point to the 'Black legged Kittiwake' and 'Arctic Skua' entries. A green box with the text 'Multiple species may be selected' is overlaid on the bottom left. The main panel shows the 'Wind Farm Features' section with input fields for 'Number of Turbines' (500), 'Latitude (deg)' (55.8), 'Width (Km)' (50), and 'Tidal Offset (m)' (2.5). A gauge for 'Speed of Flights (%)' is shown with a value of 50.

Figure 12: Species selection



### 4.3 Step 3: Species parameters

Each species selected in step 2 will now be represented under step 3. Selecting these in turn will allow the user to view and edit the species-specific parameters and data. There are many represented on the page (refer Figure 13). These are briefly listed below with some given more detailed treatment later:

1. Flight-type – either flapping or gliding. Set to flapping for this example.
2. Body length (m) estimate with uncertainty i.e. mean and standard deviation. Set to 0.39 and 0.005 for this example.
3. Wing span estimate (m) with uncertainty i.e. mean and standard deviation. Set to 1.08 and 0.04 for this example.
4. Flight speed estimate (m/s) with uncertainty i.e. mean and standard deviation. Set to 3.26 and 1.5 for this example.
5. Proportion of time active nocturnally with uncertainty i.e. mean and standard deviation<sup>5</sup>. Set to 0.033 and 0.0045 for this example.
6. Probability of basic avoidance i.e. mean and standard deviation<sup>6</sup>. Set to 0.989 and 0.001 for this example.
7. Probability of extended avoidance i.e. mean and standard deviation<sup>7</sup>. Set to 0.967 and 0.002 for this example.
8. Proportion at Collision Risk Height (CRH) i.e. mean and standard deviation<sup>8</sup>. Set to 0.06 and 0.009 for this example.
9. Flight height distributions. There are two options, by bootstrap as provided by Johnson *et al* (2014), or by upload of the users own data. A template is provided for download to ensure conformity. The example here uses Johnson's bootstraps.
10. Monthly bird density estimates by month with uncertainty i.e. mean and standard deviation. Modelled as a truncated Normal<sup>9</sup> (lower zero bounded). The example here uses Masden's figures for means and standard deviations.
11. Monthly bird density estimates by month with uncertainty i.e. mean and reference points for the distribution of the mean. A template is provided for conformity of the uploaded, which requests: Minimum, 2.5<sup>th</sup>, 5<sup>th</sup>, 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup>, 90<sup>th</sup>, 95<sup>th</sup> and 97.5<sup>th</sup> percentiles, Maximum.
12. Monthly bird density estimates by samples from the distribution of the mean. A template is provided for conformity of the uploaded, which requests 1000 draws of mean densities for each month.

Inputs 9 to 12 are given more detailed treatment below.

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<sup>5</sup> NB, these now parameterise a Beta distribution, suitable for proportions. Masden used a Normal.

<sup>6</sup> NB, these now parameterise a Beta distribution, suitable for proportions. Masden used a Normal.

<sup>7</sup> NB, these now parameterise a Beta distribution, suitable for proportions. Masden used a Normal.

<sup>8</sup> NB, these now parameterise a Beta distribution, suitable for proportions. Masden used a Normal.

<sup>9</sup> Masden used a 0-2 truncated Normal. The upper bound is removed here as per recommendation of Trinder (2017).

Black legged Kittiwake Parameters

Flight Type

☒ Flapping
☒ Gliding

Body Length (m)

0.39

SD of Body Length (m)

0.005

PDF of Black legged Kittiwake's body length

Ntile| 2.5th 25th 50th 75th 97.5th  
bodyLt| 0.3582 0.3666 0.3900 0.3934 0.3998

Wing Span (m)

1.08

SD of Wing Span (m)

0.04

PDF of Black legged Kittiwake's wing span

Ntile| 2.5th 25th 50th 75th 97.5th  
wingSpan| 1.0016 1.0530 1.0880 1.1070 1.1584

Flight Speed (m/s)

7.26

SD of Flight Speed (m/s)

1.5

PDF of Black legged Kittiwake's flight speed

Ntile| 2.5th 25th 50th 75th 97.5th  
flSpeed| 4.3201 6.2483 7.2600 8.2717 10.1999

Nocturnal Activity

0.033

SD of Nocturnal Activity

0.0045

PDF of Black legged Kittiwake's Nocturnal Activity

Ntile| 2.5th 25th 50th 75th 97.5th  
noctAct| 0.0248 0.0299 0.0328 0.0359 0.0424

Basic Avoidance

0.989

SD of Basic Avoidance

0.001

PDF of Black legged Kittiwake's basic avoidance

Ntile| 2.5th 25th 50th 75th 97.5th  
basicAvoid| 0.9870 0.9883 0.9890 0.9897 0.9909

Extended Avoidance

0.967

SD of Extended Avoidance

0.002

PDF of Black legged Kittiwake's extended avoidance

Ntile| 2.5th 25th 50th 75th 97.5th  
extAvoid| 0.9630 0.9657 0.9670 0.9684 0.9708

Proportion at CRH

0.06

SD of Proportion at CRH

0.009

PDF of Black legged Kittiwake's Collision Risk Height

Ntile| 2.5th 25th 50th 75th 97.5th  
CRHeight| 0.0436 0.0537 0.0596 0.0658 0.0788

Flight Height Distribution

Choose data source:  
☒ Johnson et al (2014)
☐ Other

Data visualisation  
☒ Bootstrap quantiles
☐ Bootstrap samples

Proportion of Black legged Kittiwake flying at 1m height intervals (medians and 95% intervals of bootstrap data) - Default Data

Source: Johnson et al (2014)

Monthly Densities

Choose how to specify distribution of monthly bird densities  
☒ Truncated Normal
☐ Distribution reference points
☐ Distribution samples

Provide the means and standard deviations of monthly densities, assuming Truncated Normals bounded at 0

	January	February	March	April	May	June	July	August	September	October	November	December
Mean birds/km²	0.97	1.04	1.15	0.48	0.56	0.63	0.68	0.64	0.53	1.20	1.02	0.99
SD of birds/km²	0.67	0.75	0.78	0.36	0.58	0.45	0.47	0.47	0.39	0.78	0.61	0.70

Black legged Kittiwake (Median and 95% CI)

Figure 13: Species parameter page

### 4.3.1 Species flight height distributions

The height at which birds fly makes them more or less vulnerable to collision with the rotor. In its simplest expression, a proportion of the birds are estimated to be within the arc of the rotor, as given in the proportion at CRH parameters.

Two options are given for a more complex treatment – either through the species-specific flight-height distributions generate from Johnston *et al* (2014), or through distributions provided by the user. The app contains the same datasets as provided in the Masden code<sup>10</sup>. The bootstrapped variants may be used, as selected and viewed in two ways in Figure 14 and Figure 15.

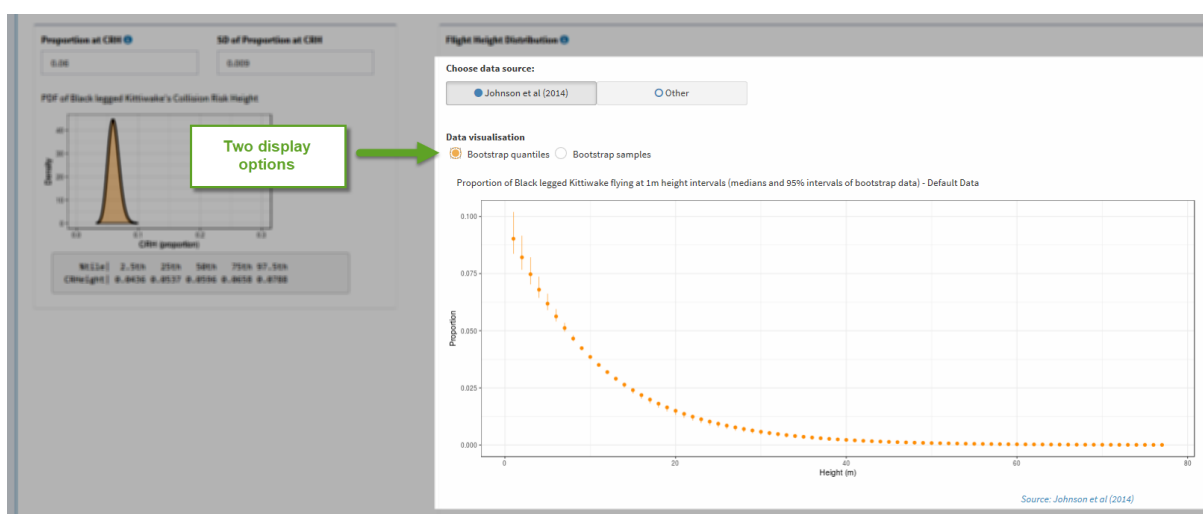


Figure 14: Flight height distributions by stored bootstraps

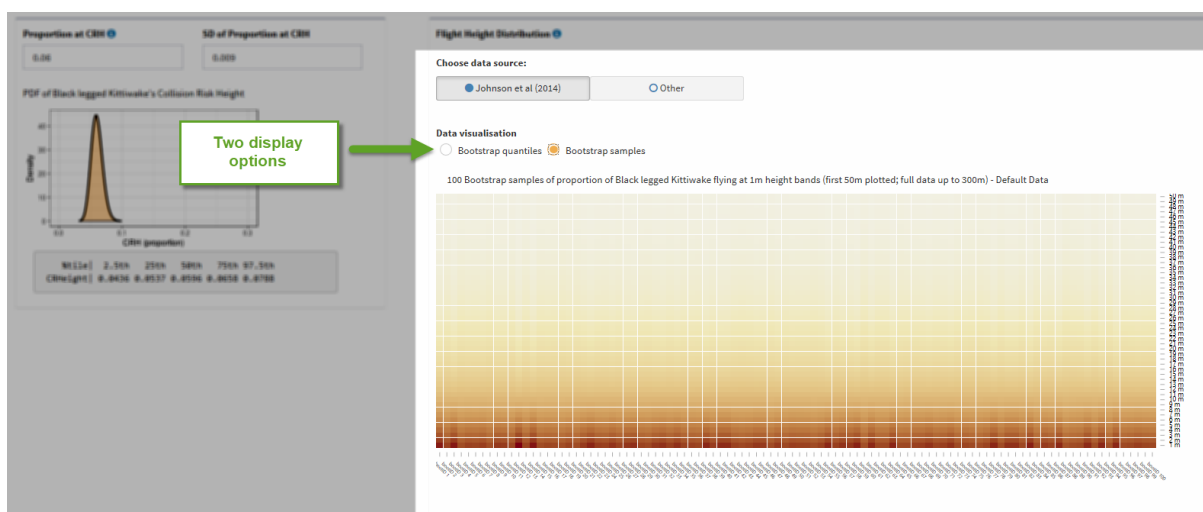


Figure 15: Flight height distributions by stored bootstraps

<sup>10</sup> These files are the “X\_ht.csv” files of Masden’s code, where X is the specific species code, which needed to conform strictly to filename and internal naming conventions.

Alternatively, users may upload their own flight-height distributions, as per Figure 16. Under this scenario, a file of bootstrapped distributions are uploaded. To ensure consistency of format, a template is available for download with this option. A file of this structure can then be uploaded to the app for the calculations.

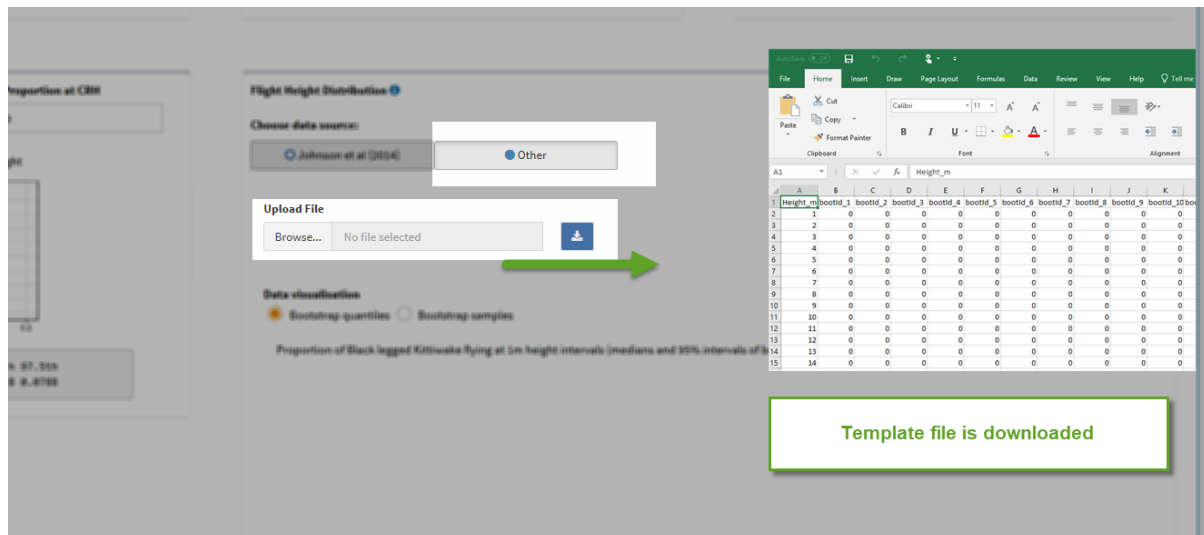


Figure 16: Flight height distributions by uploaded bootstraps

### 4.3.2 Bird densities

Three options are provided for the bird densities through time (monthly).

The first, referred to the “truncated Normal” mirrors that of Masden’s original code, but with the upper bound of the truncated Normal distribution removed (previously it was upper-bounded at 2). Data is entered as monthly means and standard deviations (Figure 17). A recommendation from the review in Trinder (2017) was this be removed. Simple means and standard deviations are required for each month<sup>11</sup>.

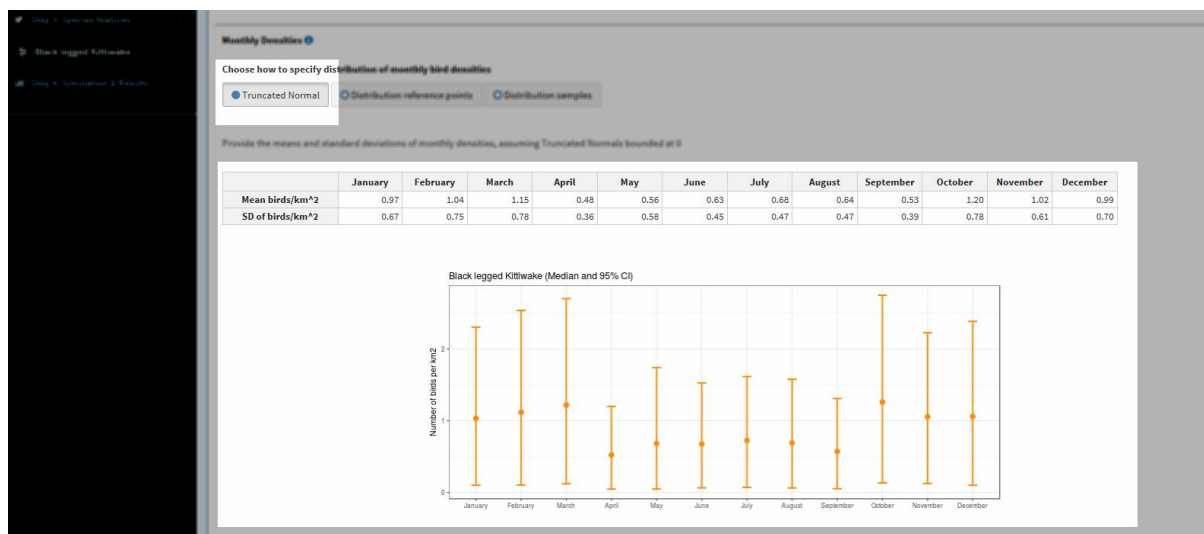


Figure 17: Bird densities via a truncated Normal distribution

The second option is by providing reference points (max, min and selected percentiles) for the user’s distribution of mean density. A template can be downloaded with this option (Figure 18), that provides a CSV file to be filled. The file is then uploaded for analysis.

<sup>11</sup> Previously this would be specified in the Masden code via a CSV file (the “count.csv” file), adhering to strict naming conventions of the file and contents.

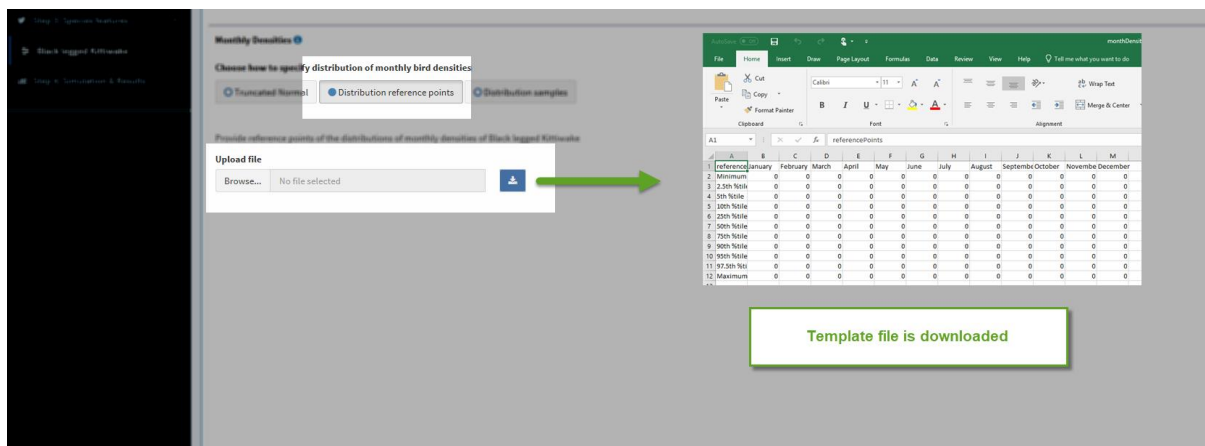


Figure 18: Bird densities via reference points of a distribution of the mean

The third option is by providing 1000 samples from the user's distribution of mean density. A template can be downloaded with this option (Figure 19), that provides a CSV file to be filled. The file is then uploaded for analysis.

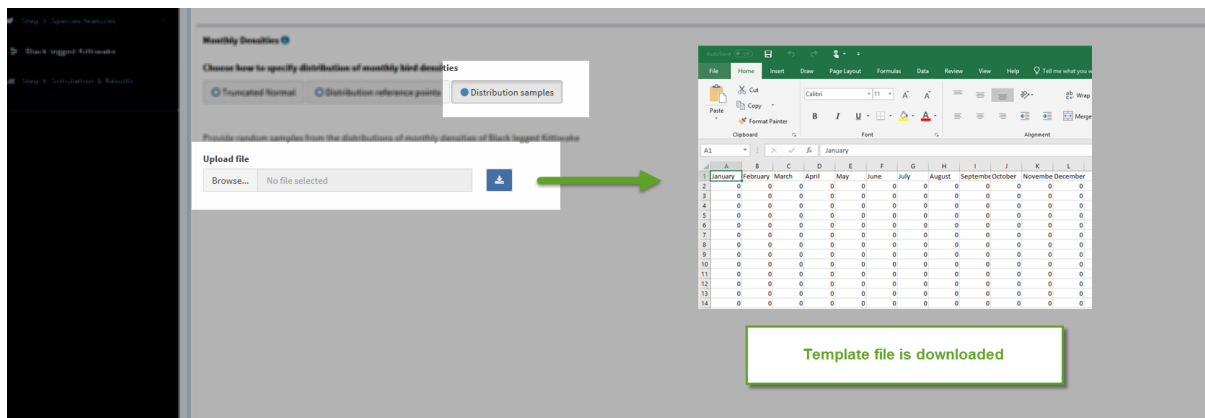


Figure 19: Bird densities via random samples from the distribution of the mean

These options ought to be sufficiently flexible to accommodate any distribution of densities desired by users. Regardless of their underpinnings (theoretical distribution or empirical resampling method), the user should be able to express these to their satisfaction under the final two options.

## 4.4 Step 4: Running the simulation

Running the simulation is straight-forwards. The number of iterations is selected (1000+ is suggested for a serious run), noting calculation time is linear with this. A run of 1000 iterations for a single species will take 2-3 minutes, so small numbers should be used during experimentation.

Note, this is also where the correction for large arrays is selected. For this example, the large array correction has been applied.

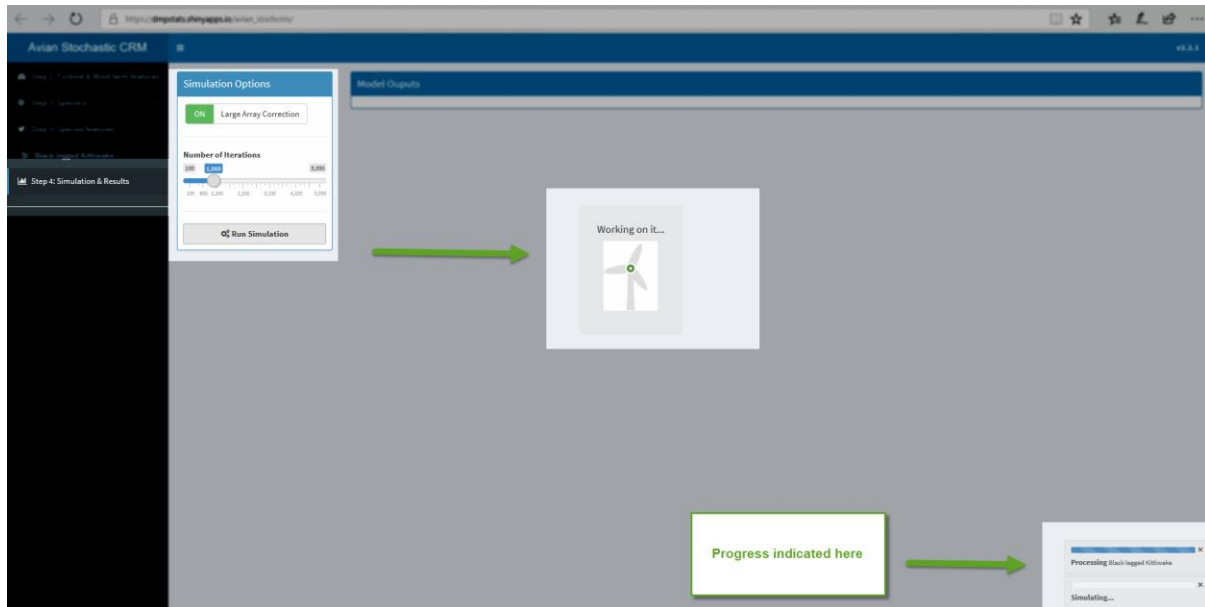


Figure 20: running the simulations

## 4.5 Model outputs

The model outputs largely mirror that of Masden, where the information is provided both as tables and figures, for the species requested. Results are provided for the basic (Options 1 and 2) and extended (Option 3) versions of the model (refer to Masden for details<sup>12</sup>). In brief:

- Option 1 uses the so-called basic model and uses a simple proportion of birds within the rotor reach – applied uniformly over the rotor.
- Option 2 also uses the so-called basic model but uses flight height distributions.
- Option 3 uses the extended model and flight height distributions.

The outputs are summarized in Figure 21. The broad features are numbered therein:

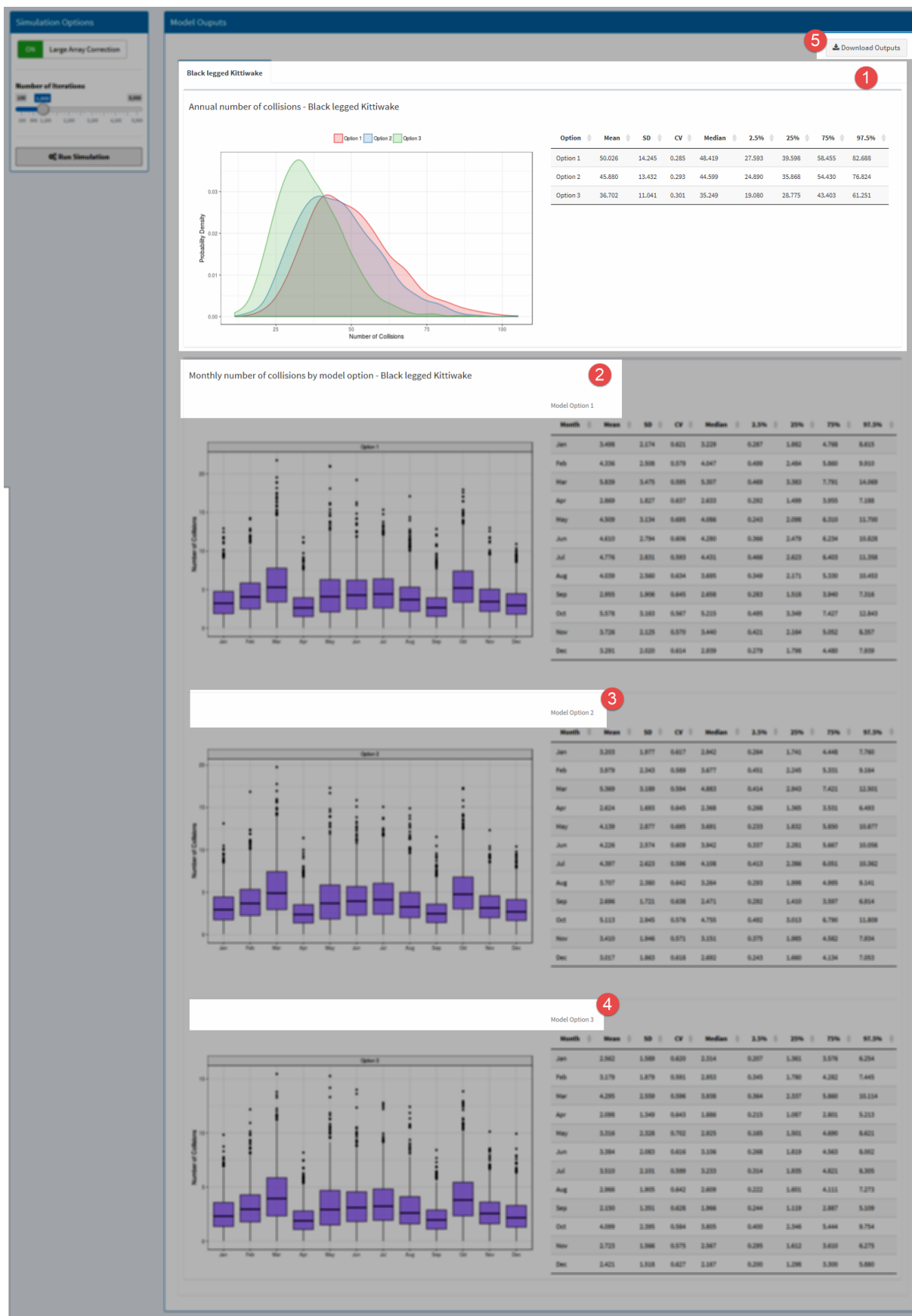
1. Overall collision risk summary, comparing the three model options in terms of distributions of collisions.
2. Individual outputs by month for the option 1 model.
3. Individual outputs by month for the option 2 model.
4. Individual outputs by month for the option 3 model.
5. An option to download all the displayed outputs, and a variety of additional outputs, as a zip file.

The output zip file also contains summaries of all the stochastic inputs, so they can be subsequently sense-checked.

---

<sup>12</sup> Masden notes that in the “basic model (options 1 & 2) uncertainty in the proportion of birds at risk height is only introduced when estimating the flux rate”. Whereas in the “extended model (option 3), the uncertainty in the flight height distribution is introduced when calculating the collision integral”.





## 5 References

- Band, B. (2012) Using a collision risk model to assess bird collision risks for offshore windfarms. SOSS report, The Crown Estate.
- Cook, A. S. C. P., Humphreys, E. M., Masden, E. A., and Burton, N. H. K. (2014) The avoidance rates of collision between birds and offshore turbines. BTO Research Report No. 656. <http://www.scotland.gov.uk/Publications/2014/12/1666/0>
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