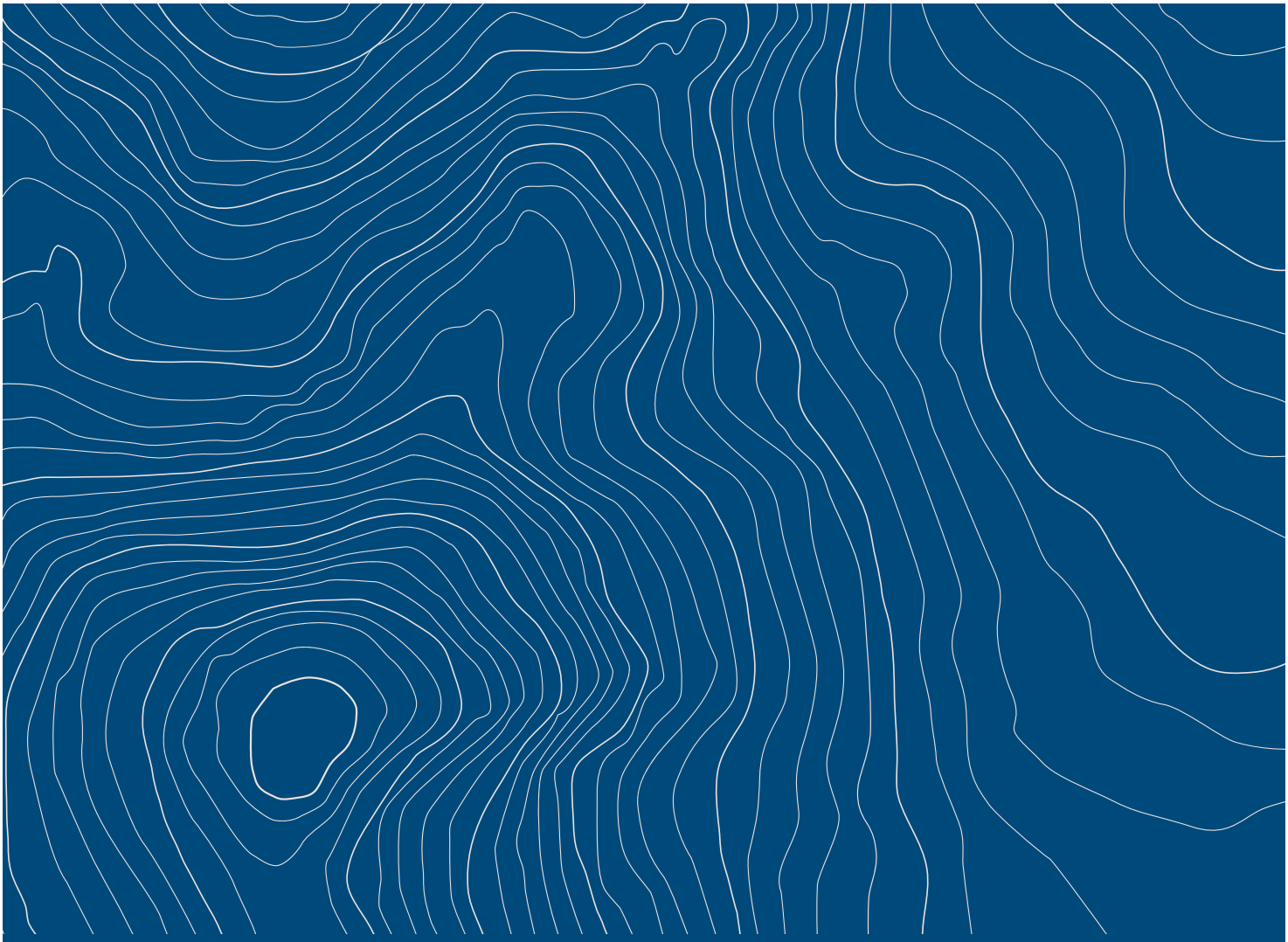

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# EIAR Volume 4: Offshore Infrastructure
# Technical Appendices
# Appendix 4.3.6-4
# Seabird Collision Risk Modelling

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# Dublin Array Offshore Wind Farm

## Environmental Impact Assessment Report

## Volume 4, Appendix 3.6-4 - Seabird Collision Risk Modelling

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# Acronyms

| Term | Definition |
|---|---|
| CRM | Collison Risk Model |
| NAF | Nocturnal Activity Factors |
| PRH | Proportion at Rotor Height |

# Glossary

| Term | Definition |
|---|---|
| Collision risk modelling | A model which is typically used in Offshore Wind Farm assessments to estimate the number of birds which may collide with turbines in each calendar month. Monthly estimates are summed for the annual total. |
| Ornithology | The study of birds |
| Stochastic | Derived from or related to a random process or probability distribution. |

# 1 Introduction

1.1.1 Collision risk modelling (CRM) is used in wind farm impact assessments to estimate the number of birds which may collide with turbines in each calendar month and summed for the annual total. The CRM which is most commonly used for offshore collision predictions in regions where offshore wind has become established is the Band (2012) model. This was developed from the onshore wind farm assessment model (Band 2000, Band *et al.* 2007). To incorporate uncertainty in input parameters the Band (2012) model has been updated to a simulation based tool (McGregor *et al.* 2018, Caneco *et al*. 2022) which has been used for current collision modelling. The model skeleton remains the same, but multiple iterations of the model can now be straightforwardly undertaken with the input parameter values for each run drawn at random from appropriate probability distributions. Outputs are provided as the mean estimates with measures of uncertainty (e.g. standard deviation, confidence intervals etc.)

1.1.2 This report provides the inputs and results for seabird CRM of the Dublin Array Offshore Wind Farm. This analysis and report have been prepared by MacArthur Green.

# 2 Methodology

2.1.1 Collision Risk Modelling (CRM) was conducted using the stochastic implementation of the Band (2012) model provided as scripts in the R programming environment (package: stochLAB v.1.1.2; Caneco *et al*. 2022). This model uses seabird data (both site-specific and generic) and turbine data to estimate the predicted number of collisions for each species per month, with uncertainty incorporated through the use of mean and standard deviation parameter values and appropriate probability distributions. The Band CRM can be run in one of two versions, referred to as basic and extended models, and within each version there is a further division depending on the source of seabird flight height estimates used; derived from either site-specific surveys or published outputs from a pooled analysis (Johnston *et al.* 2014). Thus, there are four model 'options' available:

- Option 1 – **basic** model, **site-based** flight heights,
- Option 2 – **basic** model, **generic** flight heights,
- Option 3 – **extended** model, **generic** flight heights, and
- Option 4 – **extended** model, **site-based** flight heights.

2.1.2 The basic version of the model assumes uniform seabird flight height distributions (and hence uses a single value for the proportion of birds at rotor height), while the extended version applies more realistic information about seabird flight heights using model derived estimates of the proportion of birds in 1m height bands from sea level to 300m. Most individuals of seabird species fly close to the sea surface, with the proportion of individuals present in higher height bands decreasing with increasing altitude. The extended model incorporates this behavioural information, together with the lower collision risks at the rotor tips (due to the lower percentage of rotor blade area within the rotor sweep area). However, while the theoretical basis for the extended model is accepted as more realistic, in particular that the use of flight height distributions is a better reflection of seabird flight characteristics, there is disagreement about the accuracy of the available survey data used to model the species-specific curves (JNCC *et al.* 2014). Consequently, the extended model has not become widely accepted for wind farm consenting purposes and assessments continue to be based on outputs from the basic model. Therefore, following the example of industry best practice in more established offshore wind markets (such as the UK), the basic model has been used here for the current modelling.

2.1.3 The estimate of the proportion of birds at rotor height (PRH) can be calculated from site survey data, for use in option 1 of the basic Band model, or from the generic dataset in Johnston *et al.* (2014) for use in option 2 of the basic model. In common with UK best practice, the generic flight height data have been used for the current modelling (i.e. option 2). The generic flight height data (Johnston *et al.* 2014) do not include roseate tern, thus for this species Sandwich tern flight height data were used.

2.1.4 In addition to flight height data, the following parameters were used in the model:

- Average density of seabirds in flight in each calendar month within the wind farm boundary (Table 1), obtained from analysis of the seabird survey data (see Appendix 4.3.6-1: Offshore Ornithology Technical Baseline).
- Seabird dimensions and flight characteristics:
  - Body length (average and SD);
  - Wingspan (average and SD);
  - Flight speed (average and SD);
  - Nocturnal activity (average and SD; from Garthe and Hüppop (2004), unless otherwise stated); and
  - Avoidance rate (average and SD).
- Turbine data:
  - Number of turbines;
  - Rotor radius (m);
  - Average revolutions per minute (RPM);
  - Average blade pitch (degrees);
  - Maximum blade width (chord, m)
  - Hub height (m from mean sea level); and
  - Monthly percentage of time operational.

2.1.5 The values used for the modelling are provided in Table 1 (seabird densities), Table 2 (seabird biometrics) and Table 3 (wind farm specifications) with sources where appropriate.

2.1.6 A key parameter in the CRM is the species-specific avoidance rate, which accounts for the fact that birds will take action to avoid colliding with the rotors (at a range of scales, from the whole wind farm to individual turbine blades). This adjustment is required in the model since baseline survey data are collected before turbines are present and hence do not contain any avoidance behaviour. The avoidance rates used for each species have been derived from reviews of evidence from onshore studies and theoretical modelling (e.g. Cook *et al.* 2014 and JNCC *et al.*, 2014; Ozsanlav-Harris *et al.* 2022).

2.1.7 Nocturnal Activity Factors (NAF) are applied in the CRM to enable daytime activity (as derived from the survey data) to be extrapolated to include activity at night. The rates originally applied in the Band (2012) model were derived from reviews of seabird activity reported in Garthe and Hüppop (2004), which ranked species from 1 to 5 (1 low, 5 high) to indicate nocturnal activity levels relative to daytime activity levels. These rates were subsequently modified by Band (2012) for the purposes of CRM into 1 = 0%, 2 = 25%, 3 = 50%, 4 = 75% and 5 = 100% flying activity at night.

2.1.8 The original NAF values for key collision risk species were defined as 2 for gannet (i.e. 25%) and 3 for kittiwake and the large gull species (i.e. 50%). However, Garthe and Hüppop (2004) did not intend for their results to be applied in this manner (i.e. as absolute rates). Subsequent reviews of seabird studies have indicated that the existing rates over-estimate nocturnal activity for all these species. For example, Furness *et al.*, (2018) reviewed gannet studies and recommended evidence-based relative nocturnal activity rate estimates of 8% in the breeding season and 4% in the nonbreeding season.

2.1.9 Current guidance from Natural England has been followed on NAF rates for use in the stochastic CRM (Natural England 2022).

Table 1 Monthly density (mean and standard deviation) of seabirds recorded in flight in the wind farm (birds/km$^2$).

| Species | Jan | Feb | Mar | Apr | | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic tern | 0 (0) | 0 (0) | 0 (0) | 0 (0) | | 0.068 (0.049) | 0.063 (0.044) | 0.055 (0.04) | 0.147 (0.076) | 0.046 (0.031) | 0 (0) | 0 (0) | 0 (0) |
| Black-headed gull | 0.012 (0.009) | 0 (0) | 0 (0) | 0 (0) | | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0.016 (0.012) | 0.109 (0.048) | 0.202 (0.131) |
| Common gull | 0.208 (0.106) | 0 (0) | 0.054 (0.028) | 0 (0) | | 0 (0) | 0.016 (0.012) | 0 (0) | 0 (0) | 0.005 (0.004) | 0.024 (0.016) | 0.124 (0.053) | 0.253 (0.125) |
| Common tern | 0 (0) | 0 (0) | 0 (0) | 0.012 (0.009) | | 0.252 (0.154) | 0.063 (0.032) | 0.372 (0.143) | 0.607 (0.297) | 0.524 (0.207) | 0 (0) | 0 (0) | 0 (0) |
| Great black-backed gull | 0.023 (0.018) | 0.123 (0.083) | 0.044 (0.03) | 0.046 (0.03) | | 0.008 (0.006) | 0.014 (0.011) | 0.039 (0.024) | 0.05 (0.028) | 0.022 (0.017) | 0.049 (0.032) | 0.072 (0.041) | 0.068 (0.044) |
| Gannet | 0.012 (0.009) | 0.082 (0.052) | 0.114 (0.048) | 0.587 (0.18) | | 0.522 (0.248) | 0.319 (0.152) | 0.206 (0.084) | 0.205 (0.092) | 0.289 (0.111) | 0.102 (0.044) | 0 (0) | 0.016 (0.012) |
| Herring gull | 0.138 (0.085) | 0.49 (0.188) | 0.202 (0.086) | 0.08 (0.038) | | 0.189 (0.128) | 0.067 (0.038) | 0.25 (0.087) | 0.244 (0.116) | 0.097 (0.054) | 0.102 (0.057) | 0.428 (0.134) | 0.403 (0.123) |
| Kittiwake | 0.151 (0.062) | 0.041 (0.031) | 0.636 (0.258) | 0.721 (0.17) | | 0.928 (0.524) | 1.496 (0.304) | 0.953 (0.171) | 0.404 (0.116) | 0.387 (0.147) | 1.46 (0.523) | 0.329 (0.128) | 0.608 (0.309) |
| Lesser black-backed gull | 0 (0) | 0 (0) | 0.012 (0.009) | 0 (0) | | 0.035 (0.024) | 0.024 (0.015) | 0.035 (0.024) | 0.145 (0.053) | 0.008 (0.006) | 0.012 (0.012) | 0.024 (0.015) | 0.012 (0.009) |
| Roseate tern | 0 (0) | 0 (0) | 0 (0) | 0 (0) | | 0 (0) | 0.024 (0.012) | 0.04 (0.024) | 0.03 (0.021) | 0.079 (0.054) | 0 (0) | 0 (0) | 0 (0) |
| Sandwich tern | 0 (0) | 0 (0) | 0 (0) | 0 (0) | | 0 (0) | 0 (0) | 0 (0) | 0.038 (0.027) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |

Table 2 Species biometrics used in the collision risk modelling.

| Species | Body length (m) mean and SD; Robinson (2005) | Wingspan (m) mean and SD; Robinson (2005) | Flight speed (m/s) mean and SD; Pennycuick (1987), Alerstam (2007), Skov *et al.* (2018) | Nocturnal Activity Factor (%) mean and SD; Garthe and Huppop (2004), Furness *et al.* (2018), MacArthur Green (2015) | Avoidance rate mean and SD; Cook *et al.* (2014), JNCC *et al.* (2014), Bowgen and Cook (2018), Natural England (2022) |
|---|---|---|---|---|---|
| Arctic tern | 0.33 (0) | 0.87 (0) | 10.5 (0) | 0 | 0.991 (0.0004) |
| Black-headed gull | 0.37 (0) | 1.10 (0) | 11.9 (0) | 25 (0) | 0.995 (0.0002) |
| Common gull | 0.42 (0) | 1.30 (0) | 13.4 (0) | 25 (0) | 0.995 (0.0002) |
| Common tern | 0.33 (0) | 0.87 (0) | 10.5 (0) | 0 | 0.991 (0.0004) |
| Great black-backed gull | 0.71 (0.035) | 1.58 (0.0375) | 13.7 (1.2) | 37.5 (6.37) | 0.994 (0.0004) |
| Gannet | 0.94 (0.0325) | 1.72 (0.0375) | 14.9 (0) | 8 (10) | 0.9979* (0.0003) |
| Herring gull | 0.60 (0.0225) | 1.44 (0.03) | 12.8 (1.8) | 37.5 (6.37) | 0.994 (0.0004) |
| Kittiwake | 0.39 (0.005) | 1.08 (0.0625) | 8.71 (0.4) or 13.1 (0.4) # | 37.5 (6.37) | 0.993 (0.0003) |
| Lesser black-backed gull | 0.58 0.03) | 1.42 (0.0375) | 13.1 (1.9) | 37.5 (6.37) | 0.994 (0.0004) |
| Roseate tern | 0.36 (0) | 0.76 (0) | 10.5 (0) | 0 | 0.991 (0.0004) |
| Sandwich tern | 0.39 (0.005) | 1.00 (0.04) | 10.5 (3.4) | 0 | 0.991 (0.0004) |

* Incorporates macro (whole wind farm) avoidance at 70% as per Natural England (2022).
# The higher rate has been used in this assessment

Table 3 Wind turbine parameters used in the collision risk modelling.

| Turbine model option | Average RPM | Rotor radius (m) | Hub height (m. above MSL) | Predicted operation time (%) | Max. blade width (m) | Average blade pitch (°) | No. of turbines | Latitude (°) | Tidal offset (m., difference between mean highwater springs and mean sea level) |
|---|---|---|---|---|---|---|---|---|---|
| A | 5 | 118 | 147.5 | 99 | 8.5 | 2.4 | 50 | 53.23 | 0 |
| B | 4.7 | 125 | 154.5 | 99 | 9.0 | 2.4 | 45 | 53.23 | 0 |
| C | 4.2 | 139 | 168.5 | 99 | 10.0 | 2.3 | 39 | 53.23 | 0 |

# 3 Results

3.1.1 The monthly and annual collision predictions obtained using stochastic Band CRM are presented in Table 4, Table 5 and Table 6 for each of the three turbine options.

Table 4: Stochastic Band Collision Risk Model (option 2) mortality predictions for the Dublin Array Offshore Wind Farm using Turbine Option A (this represents the maximum design option (MDO)). Values are the monthly mean and 95% confidence intervals and the sum of these for the annual estimate, with the range derived using the equivalent densities (mean and 95% c.i.). Input parameters are those listed in Table 1 to Table 3. For species with alternative input parameter estimates (Table 2) multiple rows are presented, with the respective inputs identified.

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.05 (0-0.12) | 0.05 (0.01-0.11) | 0.04 (0-0.1) | 0.1 (0.02-0.19) | 0.03 (0-0.06) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.27 (0.03-0.57) |
| Black-headed gull | 0.03 (0-0.06) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.05 (0-0.1) | 0.24 (0.05-0.44) | 0.46 (0.05-0.94) | 0.78 (0.11-1.55) |
| Common gull | 1.04 (0.17-2) | 0 (0-0) | 0.33 (0.06-0.64) | 0 (0-0) | 0 (0-0) | 0.13 (0.01-0.28) | 0 (0-0) | 0 (0-0) | 0.03 (0-0.07) | 0.14 (0.01-0.31) | 0.6 (0.14-1.12) | 1.23 (0.25-2.32) | 3.51 (0.64-6.75) |
| Common tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.02 (0-0.04) | 0.47 (0.07-0.99) | 0.11 (0.02-0.22) | 0.67 (0.17-1.17) | 1.02 (0.13-1.87) | 0.71 (0.15-1.26) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 2.99 (0.55-5.56) |
| Great black-backed gull | 0.34 (0.03-0.8) | 1.79 (0.17-3.92) | 0.76 (0.06-1.69) | 0.81 (0.09-1.83) | 0.16 (0.01-0.37) | 0.29 (0.03-0.64) | 0.8 (0.11-1.65) | 0.9 (0.11-1.83) | 0.4 (0.05-0.93) | 0.79 (0.08-1.78) | 1.02 (0.13-2.23) | 0.94 (0.1-2.1) | 9 (0.97-19.77) |
| Gannet | 0.01 (0-0.03) | 0.08 (0.01-0.19) | 0.14 (0.03-0.27) | 0.78 (0.29-1.37) | 0.82 (0.16-1.77) | 0.5 (0.07-1) | 0.33 (0.09-0.61) | 0.3 (0.06-0.57) | 0.36 (0.1-0.69) | 0.11 (0.02-0.23) | 0 (0-0) | 0.02 (0-0.04) | 3.45 (0.82-6.77) |
| Herring gull | 1.78 (0.2-3.93) | 5.72 (1.57-10.37) | 2.82 (0.67-5.22) | 1.16 (0.2-2.32) | 3.23 (0.31-7.83) | 1.13 (0.11-2.37) | 4.07 (1.25-7.11) | 3.73 (0.71-7.63) | 1.4 (0.2-3.01) | 1.36 (0.13-2.87) | 4.97 (1.78-8.44) | 4.63 (1.63-8.03) | 36.01 (8.75-69.13) |
| Kittiwake (flight speed 8.71ms$^{-1}$) | 0.46 (0.11-0.85) | 0.14 (0.01-0.31) | 2.24 (0.69-4.05) | 2.63 (1.49-3.87) | 3.81 (0.62-7.56) | 5.91 (3.5-8.67) | 3.85 (2.48-5.46) | 1.55 (0.6-2.46) | 1.33 (0.37-2.36) | 4.78 (1.42-8.26) | 0.97 (0.25-1.71) | 1.85 (0.34-3.73) | 29.5 (11.88-49.3) |

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kittiwake (flight speed 13.1ms$^{-1}$) | 0.64 (0.13-1.14) | 0.19 (0.01-0.43) | 3.13 (0.95-5.7) | 3.7 (1.96-5.45) | 5.37 (0.57-10.93) | 8.5 (5.13-12.46) | 5.54 (3.64-7.53) | 2.22 (1.01-3.53) | 1.89 (0.4-3.3) | 6.94 (2.23-12.33) | 1.39 (0.34-2.5) | 2.62 (0.38-5.2) | 42.13 (16.77-70.5) |
| Lesser black-backed gull | 0 (0-0) | 0 (0-0) | 0.15 (0.01-0.36) | 0 (0-0) | 0.52 (0.05-1.2) | 0.34 (0.03-0.73) | 0.53 (0.05-1.25) | 1.89 (0.57-3.4) | 0.1 (0.01-0.22) | 0.17 (0.01-0.4) | 0.24 (0.02-0.55) | 0.13 (0.01-0.28) | 4.07 (0.77-8.39) |
| Roseate tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.04 (0.01-0.08) | 0.07 (0.01-0.15) | 0.05 (0-0.11) | 0.11 (0.01-0.24) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.27 (0.03-0.57) |
| Sandwich tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.07 (0-0.16) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.07 (0-0.16) |

Table 5 Stochastic Band Collision Risk Model (option 2) mortality predictions for the Dublin Array Offshore Wind Farm using **Turbine Option B**. Values are the monthly mean and 95% confidence intervals and the sum of these for the annual estimate, with the range derived using the equivalent densities (mean and 95% c.i.). Input parameters are those listed in Table 1 to Table 3. For species with alternative input parameter estimates (Table 2) multiple rows are presented, with the respective inputs identified.

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.05 (0.01-0.11) | 0.05 (0-0.1) | 0.04 (0-0.09) | 0.09 (0.01-0.18) | 0.03 (0-0.05) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.25 (0.03-0.53) |
| Black-headed gull | 0.03 (0-0.06) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.04 (0-0.09) | 0.23 (0.04-0.42) | 0.44 (0.05-0.9) | 0.74 (0.09-1.47) |
| Common gull | 0.95 (0.15-1.88) | 0 (0-0) | 0.31 (0.04-0.6) | 0 (0-0) | 0 (0-0) | 0.12 (0.01-0.26) | 0 (0-0) | 0 (0-0) | 0.03 (0-0.07) | 0.14 (0.01-0.3) | 0.58 (0.13-1.03) | 1.16 (0.21-2.28) | 3.3 (0.56-6.42) |
| Common tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.02 (0-0.04) | 0.43 (0.04-0.88) | 0.11 (0.02-0.22) | 0.63 (0.17-1.1) | 0.92 (0.15-1.81) | 0.67 (0.19-1.19) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 2.78 (0.56-5.24) |
| Great black-backed gull | 0.33 (0.03-0.73) | 1.66 (0.15-3.68) | 0.7 (0.06-1.55) | 0.73 (0.06-1.58) | 0.15 (0.01-0.34) | 0.27 (0.03-0.6) | 0.71 (0.08-1.49) | 0.82 (0.11-1.72) | 0.37 (0.03-0.82) | 0.75 (0.07-1.68) | 0.96 (0.09-1.96) | 0.93 (0.08-2.02) | 8.38 (0.81-18.19) |
| Gannet | 0.01 (0-0.03) | 0.07 (0.01-0.16) | 0.13 (0.03-0.24) | 0.73 (0.25-1.29) | 0.77 (0.14-1.49) | 0.47 (0.07-0.96) | 0.3 (0.06-0.56) | 0.27 (0.05-0.53) | 0.33 (0.09-0.6) | 0.11 (0.02-0.21) | 0 (0-0) | 0.01 (0-0.03) | 3.2 (0.73-6.11) |
| Herring gull | 1.65 (0.2-3.5) | 5.31 (1.46-9.65) | 2.74 (0.67-5.05) | 1.08 (0.18-2.09) | 3.07 (0.37-6.89) | 1.05 (0.13-2.15) | 3.79 (1.21-6.65) | 3.62 (0.48-7.15) | 1.3 (0.17-2.76) | 1.33 (0.2-2.67) | 4.85 (1.66-8.53) | 4.47 (1.69-7.75) | 34.27 (8.41-64.83) |
| Kittiwake (flight speed 8.71ms$^{-1}$) | 0.42 (0.1-0.75) | 0.13 (0.01-0.28) | 2.1 (0.56-3.72) | 2.45 (1.34-3.65) | 3.65 (0.43-7.43) | 5.58 (3.23-7.93) | 3.62 (2.28-5.02) | 1.45 (0.63-2.28) | 1.27 (0.32-2.21) | 4.57 (1.3-8.24) | 0.93 (0.29-1.7) | 1.73 (0.19-3.36) | 27.9 (10.69-46.56) |

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kittiwake (flight speed 13.1ms$^{-1}$) | 0.6 (0.15-1.08) | 0.18 (0.02-0.4) | 3.08 (0.91-5.59) | 3.51 (1.87-5.13) | 5.23 (0.48-10.31) | 8.06 (4.54-11.43) | 5.26 (3.38-7.31) | 2.09 (0.9-3.35) | 1.82 (0.45-3.28) | 6.46 (1.92-10.85) | 1.32 (0.37-2.27) | 2.41 (0.39-4.85) | 40.02 (15.37-65.84) |
| Lesser black-backed gull | 0 (0-0) | 0 (0-0) | 0.15 (0.01-0.34) | 0 (0-0) | 0.49 (0.04-1.11) | 0.32 (0.03-0.71) | 0.49 (0.05-1.13) | 1.76 (0.51-3.24) | 0.09 (0.01-0.23) | 0.16 (0.01-0.39) | 0.23 (0.02-0.54) | 0.12 (0.01-0.29) | 3.83 (0.69-7.98) |
| Roseate tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.04 (0.01-0.07) | 0.07 (0.01-0.14) | 0.05 (0-0.1) | 0.1 (0.01-0.23) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.26 (0.03-0.55) |
| Sandwich tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.06 (0.01-0.15) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.06 (0.01-0.15) |

Table 6 Stochastic Band Collision Risk Model (option 2) mortality predictions for the Dublin Array Offshore Wind Farm using **Turbine Option C**. Values are the monthly mean and 95% confidence intervals and the sum of these for the annual estimate, with the range derived using the equivalent densities (mean and 95% c.i.). Input parameters are those listed in Table 1 to Table 3. For species with alternative input parameter estimates (Table 2) multiple rows are presented, with the respective inputs identified.

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arctic tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.05 (0-0.11) | 0.05 (0-0.1) | 0.04 (0-0.09) | 0.09 (0.01-0.18) | 0.03 (0-0.05) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.25 (0.03-0.53) |
| Black-headed gull | 0.03 (0-0.05) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.04 (0-0.09) | 0.21 (0.05-0.4) | 0.41 (0.04-0.87) | 0.69 (0.09-1.41) |
| Common gull | 0.92 (0.13-1.77) | 0 (0-0) | 0.3 (0.05-0.58) | 0 (0-0) | 0 (0-0) | 0.11 (0.01-0.24) | 0 (0-0) | 0 (0-0) | 0.03 (0-0.06) | 0.13 (0.02-0.29) | 0.56 (0.15-1.04) | 1.07 (0.21-2.06) | 3.12 (0.56-6.04) |
| Common tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.02 (0-0.04) | 0.42 (0.04-0.88) | 0.1 (0.02-0.2) | 0.59 (0.17-1.04) | 0.9 (0.14-1.71) | 0.64 (0.14-1.16) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 2.67 (0.52-5.02) |
| Great black-backed gull | 0.32 (0.03-0.72) | 1.52 (0.13-3.28) | 0.68 (0.07-1.5) | 0.7 (0.07-1.46) | 0.14 (0.01-0.31) | 0.25 (0.02-0.59) | 0.69 (0.08-1.5) | 0.78 (0.1-1.59) | 0.36 (0.03-0.81) | 0.7 (0.06-1.48) | 0.87 (0.11-1.82) | 0.88 (0.1-1.87) | 7.89 (0.8-16.94) |
| Gannet | 0.01 (0-0.03) | 0.07 (0.01-0.16) | 0.12 (0.03-0.23) | 0.68 (0.25-1.15) | 0.72 (0.14-1.45) | 0.44 (0.07-0.89) | 0.28 (0.06-0.54) | 0.26 (0.06-0.5) | 0.31 (0.09-0.6) | 0.1 (0.02-0.19) | 0 (0-0) | 0.01 (0-0.03) | 3.02 (0.73-5.76) |
| Herring gull | 1.53 (0.22-3.4) | 4.88 (1.33-9.39) | 2.46 (0.61-4.72) | 1.03 (0.17-2.04) | 2.93 (0.28-6.55) | 0.98 (0.14-2.03) | 3.61 (1.12-6.35) | 3.36 (0.66-6.87) | 1.23 (0.19-2.6) | 1.22 (0.14-2.52) | 4.52 (1.71-7.96) | 4.06 (1.54-6.99) | 31.82 (8.12-61.42) |
| Kittiwake (flight speed 8.71ms$^{-1}$) | 0.39 (0.09-0.73) | 0.12 (0.01-0.27) | 1.98 (0.52-3.57) | 2.32 (1.27-3.43) | 3.5 (0.5-7.16) | 5.33 (3.23-7.42) | 3.41 (2.23-4.7) | 1.39 (0.61-2.19) | 1.19 (0.3-2.05) | 4.34 (1.51-7.23) | 0.87 (0.26-1.58) | 1.61 (0.26-3.34) | 26.45 (10.8-43.67) |

| Species | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kittiwake (flight speed 13.1ms$^{-1}$) | 0.57 (0.14-1.04) | 0.17 (0.02-0.38) | 2.79 (0.64-5) | 3.35 (1.72-4.99) | 5.07 (0.67-10.21) | 7.7 (4.3-10.92) | 4.95 (3.2-6.82) | 1.99 (0.84-3.13) | 1.77 (0.51-3.05) | 6.14 (1.97-10.53) | 1.27 (0.39-2.26) | 2.35 (0.38-4.53) | 38.12 (14.78-62.87) |
| Lesser black-backed gull | 0 (0-0) | 0 (0-0) | 0.14 (0.01-0.31) | 0 (0-0) | 0.47 (0.05-1.04) | 0.3 (0.03-0.66) | 0.47 (0.04-1.08) | 1.69 (0.54-3) | 0.09 (0.01-0.2) | 0.15 (0.01-0.38) | 0.22 (0.02-0.51) | 0.12 (0.01-0.28) | 3.65 (0.72-7.47) |
| Roseate tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.04 (0.01-0.07) | 0.06 (0.01-0.14) | 0.05 (0-0.1) | 0.1 (0.01-0.21) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.24 (0.03-0.52) |
| Sandwich tern | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.06 (0.01-0.15) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0.06 (0.01-0.15) |

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