JNCC Report 732

Review of data used to calculate avoidance rates for collision risk modelling of seabirds

Annex 5
Bird Collision Avoidance: user test

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August 2024

ISSN 0963 8091

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1 Overview

Following replacement of 'stochCRM' with the 'sCRM' shiny app (for details see Annex 4 of Ozsanlav-Harris *et al.* 2023), there was need for a user test that compares calculated avoidance rates (ARs) across previous iterations of collision risk modelling methods. These previous methods are the Band Spreadsheet (Band 2012), the stochCRM shiny app (McGregor *et al.* 2018), the sCRM shiny App (Caneco *et al.* 2022), and the stochLAB package (also Caneco *et al.* 2022) — which provides all functions behind the sCRM shiny app. We used v1 ARs from Ozsanlav-Harris *et al.* (2023) for three species groupings– 'All gulls', 'Large gulls' & 'All gulls and terns' (Table 1). Deterministic ARs were used for the Basic Band spreadsheet and deterministic option of sCRM, while stochastic ARs were used for stochCRM, sCRM and stochLAB.

Source data for four target windfarm sites (Thanet, R4 project 1 & 2, and Zeebrugge 7–12) were compiled from publicly available sources (Thanet site: Royal Haskoning DHV 2013; R4 project sites: NIRAS Group (UK) Ltd 2022; Zeebrugge 7–12 site: Everett & Stienen 2008). Key seabird species were matched to each site (kittiwake, gannet, and lesser-black backed gull for Thanet and R4 projects 1 and 2; sandwich tern for Zeebrugge 7–12), and ecological data for each of these species were collated (Table 2 & 3). Sandwich tern densities were chosen arbitrarily but set to higher end of density expected during the May–June breeding season (Harwood *et al.* 2017). Where density data was only provided with 95% confidence intervals, we coarsely estimated standard deviation assuming a normal distribution by calculating the range of the confidence interval (Upper CI minus Lower CI), divided by 1.96. Alongside species data, relevant data on turbine model/output and size, number and other key site data were also collated (Table 4).

Table 1: Avoidance rate data for target species from three species groups, based on Ozsanlav-Harris *et al.* 2023.

Species (AR grouping)	Model type	Avoidance rate (SD's)
Kittiwake (All gulls)	Basic Band	0.9924 (0.0001)
Kittiwake (All gulls)	Stochastic Basic Band	0.9928 (0.0003)
Kittiwake (All gulls)	Extended Band	0.9720 (0.0004)
Kittiwake (All gulls)	Stochastic Extended Band	0.9533 (0.0047)
Gannet (All gulls)	Basic Band	0.9924 (0.0001)
Gannet (All gulls)	Stochastic Basic Band	0.9928 (0.0003)
Gannet (All gulls)	Extended Band	0.9720 (0.0004)
Gannet (All gulls)	Stochastic Extended Band	0.9533 (0.0047)
Lesser b-b. gull (Large gulls)	Basic Band	0.9936 (0.0002)
Lesser b-b. gull (Large gulls)	Stochastic Basic Band	0.9939 (0.0004)
Lesser b-b. gull (Large gulls)	Extended Band	0.9774 (0.0006)
Lesser b-b. gull (Large gulls)	Stochastic Extended Band	0.9614 (0.0047)

Species (AR grouping)	Model type	Avoidance rate (SD's)
Sandwich tern (All gulls and terns)	Basic Band	0.9902 (0.0001)
Sandwich tern (All gulls and terns)	Stochastic Basic Band	0.9907 (0.0004)
Sandwich tern (All gulls and terns)	Extended Band	0.9662 (0.0004)
Sandwich tern (All gulls and terns)	Stochastic Extended Band	0.9500 (0.0038)

Table 2: Seabird parameters (transposed to long table format).

Parameter	Kittiwake	Northern gannet	Lesser black-backed gull	Sandwich Tern
Species name for FHD	"Kittiwake"	"Gannet"	"LesserBlackBackedGull"	"SandwichTern"
Bird length (m)	0.39	0.94	0.58	0.38
Bird length SD	0.005	0.0325	0.03	0.005
Wingspan	1.08	1.72	1.42	1
Wingspan SD	0.0625	0.0375	0.0375	0.04
Flight speed (m/s)	13.1	14.9	13.1	10.3
Flight speed SD	0.4	0	1.9	3.4
Flight mode	flapping	flapping	flapping	flapping
Prop. of flights at CRH	0.06	0.07	0.26	0.06
Prop. of flights at CRH SD	0.009	0.01	0.01	0.1
Flights upwind	50	50	50	50
Nocturnal activity	0.375	0.08	0.375	0.1
Nocturnal activity SD	0.0637	0.1	0.0637	0.05

Table 3: Default seasonal parameters used for user testing analyses (monthly wind availability taken from defaults provided by Masden *et al.* 2018).

Site	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
All sites	Wind availability (%)	96.28	96.53	95.83	92.78	90.86	92.22	89.11	89.92	93.71	96.14	97.14	96.41
Thanet	Kittiwake density	1.30	1.09	0.41	0.00	0.00	0.00	0.00	0.00	0.00	1.13	1.03	1.06
Thanet	Kittiwake density SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thanet	Gannet density	0.45	2.40	2.74	0.00	0.00	0.00	0.00	0.00	0.00	1.39	2.23	0.83
Thanet	Gannet density SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thanet	Lesser b-b. gull density	0.06	0.30	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.34	0.11
Thanet	Lesser b-b. gull density SD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R4 Project 1	Kittiwake density	0.48	0.52	0.54	0.53	0.45	0.36	0.28	0.24	0.23	0.27	0.34	0.42
R4 Project 1	Kittiwake density SD	0.06	0.07	0.07	0.07	0.06	0.04	0.03	0.03	0.03	0.03	0.04	0.05
R4 Project 1	Gannet density	0.04	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.07	0.05	0.04
R4 Project 1	Gannet density SD	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
R4 Project 1	Lesser b-b. gull density	0.02	0.02	0.03	0.05	0.04	0.04	0.04	0.03	0.02	0.02	0.02	0.02
R4 Project 1	Lesser b-b. gull density SD	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
R4 Project 4	Kittiwake density	0.04	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.05	0.05	0.04
R4 Project 4	Kittiwake density SD	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01

Site	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
R4 Project 4	Gannet density	0.01	0.01	0.02	0.05	0.06	0.07	0.08	0.1	0.09	0.03	0.01	0.01
R4 Project 4	Gannet density SD	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.01
R4 Project 4	Lesser b-b. gull density	0.01	0.01	0.02	0.04	0.05	0.06	0.07	0.04	0.02	0.02	0.02	0.02
R4 Project 4	Lesser b-b. gull density SD	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Zeebrugge	Sandwich tern density	0.00	0.00	0.00	0.00	0.80	0.80	0.00	0.00	0.00	0.00	0.00	0.00
Zeebrugge	Sandwich tern density SD	0.00	0.00	0.00	0.00	0.010	0.010	0.00	0.00	0.00	0.00	0.00	0.00

Table 4: Turbine parameters for each of the windfarms for the user test (transposed to long table format). 'Turbine model' for R4 project 1 and 2 were taken from planning documentation (NIRAS group Ltd 2022). 'Air gap' (distance from lowest point of turbine blade to sea level) was calculated by subtracting rotor radius from hub height. 'Tidal offset' data was not available, so the default value (2.5 m) was used for all windfarms. 'Windfarm width' (used for large array correction) was not available for R4 Projects, and so was estimated following code within the `stochLAB::get_lac_factor()` function (i.e. use total number of turbines to estimate turbine rows, multiply number of turbines in a row by the 1.5 km spacing between turbines).

Parameter	Thanet	R4 Project 1	R4 Project 4	Zeebrugge 7–12
Number of turbines	100	150	107	6
Latitude	51.5	54.62	53.73	51.36
Windfarm width (km)	8.9	18.4	15.5	1
Turbine model (output in MW)	3	10	14	0.4
Hub height (m)	70	106	140	34
Air gap (m)	25	24	30	17
Number of blades	3	3	3	3
Rotor diameter (m)	90	164	220	34
Rotor radius (m)	45	82	110	17
Blade width (m)	3.5	5.5	5.5	0.66
Rotor speed (rpm)	16.1	13.9	7.8	43
Rotor speed SD	0.05	0.05	0.05	0.05
Tidal offset (m)	2.5	2.5	2.5	2.5
Rotor pitch (degrees)	15	3	3	10
Rotor pitch SD	0.01	0.01	0.01	0.01
Monthly operation proportion	0.9	0.92	0.912	0.9
Monthly downtime proportion	0.1	0.08	0.088	0.10
Monthly operational proportion SD	0.02	0.02	0.02	0.02
Large array correction	ON	ON	ON	OFF

2 Collision risk modelling

Using all input parameters for windfarm sites, seabird species, seasonal wind availability and bird densities per site provided in Tables 1–4 above, we conducted collision risk models for key species at four windfarms. Collision risk modelling was carried out using four available methods: the Basic Band spreadsheet (Band 2012), the stochCRM shiny app (McGregor *et al.* 2018), the sCRM shiny app (Caneco *et al.* 2022), and the stochLAB package (Caneco *et al.* 2022).

For calculations conducted with the Basic Band spread sheet (Band 2012), we used species-specific flight height distribution maximum likelihood estimates (i.e. 'speciesname.est' column) from data provided Johnston *et al.* (2014). For stochCRM, sCRM, and stochLAB, flight height distributions were estimated from bootstrapped versions of the same data (Johnston 2014), which are provided as an embedded object in the stochLAB package (`generic_fhd_bootstraps`). To maximise reproducibility for comparison between calculated collisions, in both sCRM and stochLAB we set the seed to a value of "123".

Table 5: Annual collisions calculated using Band Option 2 (Basic) and v1 ARs (from Table 1). 95% confidence intervals for stochastic calculations are shown in brackets.

Species	Windfarm	Model interface (option 2)				
		Band spreadsheet	sCRM deterministic	sCRM	stochLAB	stochCRM
Kittiwake	Thanet	32.005	32.029	29.9 (21.1–39.0)	29.9 (21.1–39)	29.8 (20.3–39.8)
Kittiwake	R4 Project 1	68.628	68.668	64.3 (44.8–83.0)	64.3 (44.8–83)	64.6 (45.4–85.7)
Kittiwake	R4 Project 4	3.008	3.015	2.8 (1.8–3.9)	2.8 (1.8–3.9)	2.8 (1.8–3.8)
Gannet	Thanet	47.992	48.018	49.5 (15.6–92.5)	49.5 (15.6–92.5)	49.5 (15.0–96.1)
Gannet	R4 Project 1	10.763	10.763	11.1 (3.7–19.9)	11.1 (3.7–19.9)	11.2 (3.9–20.6)
Gannet	R4 Project 4	2.961	2.959	3.1 (0.8–6.515)	3.1 (0.8–6.5)	3.2 (0.8–6.4)
Lesser b-b. gull	Thanet	15.336	15.339	15.5 (8.8–27.7)	15.5 (8.8–27.7)	15.6 (8.5–26.3)
Lesser b-b. gull	R4 Project 1	12.247	12.249	12.8 (6.4–22.9)	12.8 (6.4–22.8)	12.5 (6.5–21.7)
Lesser b-b. gull	R4 Project 4	5.963	5.962	6.4 (2.9–12.8)	6.4 (2.9–12.8)	6.3 (2.9–12.0)
Sandwich tern	Zeebrugge	0.303	0.303	0.4 (0.2–0.6)	0.3 (0.2–0.6)	0.4 (0.2–0.6)

Table 6: Annual collisions calculated using Band Option 3 (Extended) and v1 ARs (from Table 1). 95% confidence intervals for stochastic calculations are shown in brackets.

Species	Windfarm	Model interface (option 3)				
		Band spreadsheet	sCRM deterministic	sCRM	stochLAB	stochCRM
Kittiwake	Thanet	52.291	52.403	86.1 (55.1–124.4)	86.1 (55.1–124.4)	82.3 (49.4–119.1)
Kittiwake	R4 Project 1	65.587	65.922	109.3 (69.2–156.4)	109.3 (69.2–156.4)	110.4 (66.7–164.7)
Kittiwake	R4 Project 4	2.006	2.021	3.4 (1.9–5.2)	3.4 (1.9–5.2)	3.4 (1.9–5.0)
Gannet	Thanet	82.249	82.415	158.6 (36.3–341.6)	158.6 (36.3–341.6)	158.0 (36.3–359.3)
Gannet	R4 Project 1	12.050	12.091	23.5 (5.8–49.3)	23.5 (5.8–49.3)	23.6 (6.0–50.6)
Gannet	R4 Project 4	2.390	2.399	4.8 (0.9–11.8)	4.8 (0.9–11.8)	4.9 (0.9–11.6)
Lesser b-b. gull	Thanet	34.071	34.106	64.1 (29.5–137.5)	64.1 (29.6–137.5)	62.7 (27.9–127.6)
Lesser b-b. gull	R4 Project 1	17.291	17.309	34.8 (13.8–79.4)	34.9 (13.8–79.4)	33.6 (13.3–71.1)
Lesser b-b. gull	R4 Project 4	6.043	6.054	12.7 (4.4–32.2)	12.7 (4.4–32.2)	12.4 (4.6–28.6)
Sandwich tern	Zeebrugge	0.811	0.810	1.5 (0.9–3.0)	1.5 (0.9–3)	1.5 (0.9–3.0)

3 Additional considerations

While we used grouped species ARs for all species in this user test, it should be noted that for gannets the 'All gulls' ARs only account for within-windfarm avoidance, and macro-scale avoidance should also be considered and addressed (Pavat *et al.* 2023; Table A2 - Cook 2021).

For the stochCRM shiny app, sCRM shiny app and stochLAB package, high avoidance rates with large standard deviations (e.g. AR:0.99; SD: 0.1), cannot be computed because they are incompatible with the properties of the beta distributions that are used (quite reasonably) to map the mean (μ) and SD (σ) of ARs to a (mathematically and ecologically) plausible distribution to generate uncertainty. In short, to give rise to a valid beta distribution, the variance (σ^2) should be:

$$\leq \mu(1-\mu)$$

As a result, several species-specific stochastic Extended Band ARs previously calculated (Cook 2021; Ozsanlav-Harris 2023 v1 and v2) have mean and SD pairs that are incompatible with beta distributions and cannot be used for collision risk modelling unless their standard deviations are manually reduced or set to a fixed value that would yield a valid beta distribution. An obvious recommendation would be to use a SD that means the variance is ever so slightly smaller than:

$$\mu(1-\mu)$$

For example:

$$\sigma = \sqrt{\mu(1-\mu)} \times 0.999$$

This issue suggests there could be steps during the calculation of the avoidance rates where, for example, normal distributions are being assumed where this is not appropriate. If species-specific AR are to be used in future (e.g. for kittiwake), this issue would need to first be examined and potentially addressed.

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