



Alternative density analysis report for SNH/JNCC specified breeding seasons

Statoil ASA

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**Alternative density, abundance and collision risk
mortality estimates for breeding seasons specified
by JNCC/SNH for the Hywind Scotland Pilot Park**

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The assessment of the potential impact of the Hywind Scotland project on seabirds will primarily be based on the density and abundance estimates for seabirds provided by distance sampling analyses of data collected during boat-based surveys of the waters of the Buchan Deep during the period June 2013 to May 2014 as reported in Caloo (2014a). In a separate report we use these density estimates to estimate collision risk mortality (Caloo 2014b).

The assessment of impacts, including displacement and collision risk mortality is based upon density and abundance estimates calculated for seasons specific to each species. The seasons used for each species were defined on the basis of the scientific literature, tempered by any seasonal patterns apparent in the survey data so as to reflect the biology of the species concerned on this particular site. Thus the seasons used are both species and site specific. For each species, Table 2 in NRP (2014) defines the seasons used whilst Table X presents the reasoning and supporting evidence.

In their initial response JNCC/SNH provided draft recommendations on the definition of seabird breeding periods for use in impact assessment and recommended that we take this draft advice into account in our definition of seabird seasons. Draft recommendations were provided for 10 out of the 20 species recorded during surveys. For these 10 species we followed these recommendations with respect to defining the breeding season unless the recommendations were in clear conflict with either the scientific literature or observed patterns within the data. For some of these species we also identified additional post-breeding seasons on the basis of the scientific literature and patterns in the data. For the other 10 species for which SNH/JNCC provided no recommendation we relied wholly on the scientific literature and patterns within the data when defining our seasons.

For 6 out of the 10 species (fulmar, gannet, lesser black-backed gull, common tern, guillemot and razorbill) for which JNCC/SNH provided breeding season definitions, the suite of seasons for a particular species we defined are fully compatible with their breeding season recommendations. However for four species (herring gull, kittiwake, puffin and Arctic tern) we concluded that the breeding seasons defined by JNCC/SNH were not compatible with the scientific literature and/or the observed seasonal patterns in the survey data. Therefore, for these four species we revised the seasons recommended by JNCC/SNH by the minimum possible to ensure we did have seasons that were compatible with the scientific literature and the survey data. We also defined our own seasons for great black-backed gull as this species was not included in the initial list of species for which JNCC/SNH provided draft recommendations with respect to the breeding season. However, subsequent responses imply that SNH would recommend the same breeding season for this species as for the other large gulls, April to August, which does not coincide with the summer and winter seasons we defined for this species on the basis of the scientific literature and patterns in the data.

Thus for five species (herring gull, great black-backed gull, kittiwake, Arctic tern and puffin) we have modified the breeding seasons recommended by JNCC/SNH to provide definitions that are compatible with the published scientific literature and the seasonal patterns observed in the data.

In order to maintain consistency with the other east coast projects MS-LOT have requested that the seasons recommended by JNCC/SNH be used in the assessment. However, using seasons that are not compatible with the scientific literature and observed patterns within the survey data would undermine the scientific credibility of our assessment, and is potentially misleading. Therefore in the Environmental Statement for the Hywind project we retain our definition of seasons.

However, for the five species where our definitions of seasons differ from those recommended by JNCC/SNH here we provide estimates of density and abundance based upon the seasons recommended by JNCC/SNH. For the four species where collision risk mortality could potentially be of significance (herring gull, great black-backed gull, kittiwake and Arctic tern) we also provide estimates of annual and seasonal collision risk mortality based upon the seasons recommended by JNCC/SNH.

Providing these separate estimates allows MS-LOT, MSS, SNH and JNCC to make comparisons with the other east coast projects on their chosen basis whilst maintaining the scientific credibility of our assessment. It can also potentially provide reassurance to these bodies that the conclusions of our assessment are robust to our definition of seasons.

In calculating our estimates of density and abundance and collision risk mortality we have followed exactly the same approach as Caloo (2014a) and Caloo (2014b), and these two reports should be consulted for further explanation of the methods and underlying logic.

The results provided are as follows:

- Figure 1 shows the different strata used in the calculation of density and abundance estimates
- Table 1 provides the seasons as defined by JNCC and SNH for the five species for which their definition of the breeding season differs from that used in the assessment.
- Table 2 provides density estimates for each species for JNCC/SNH seasons based on survey effort across the whole survey area.
- Table 3 provides density estimates for puffins during the JNCC/SNH breeding season based on survey effort within the Northern Survey Area.
- Table 4 provides abundance estimates for the whole survey area, based upon survey effort across the whole study survey area.
- Table 5 provides abundance estimates for a 1 km buffer around the turbines, based upon density estimates for the whole survey area, apart from the estimates for puffin during the breeding season, which are based upon density estimates for the Northern Survey Area.
- Table 6 provides abundance estimates for a 2 km buffer around the turbines, based upon density estimates for the whole survey area, apart from the estimates for puffin during the breeding season, which are based upon density estimates for the Northern Survey Area.
- Table 7 provides abundance estimates for a 3 km buffer around the turbines, based upon density estimates for the whole survey area, apart from the estimates for puffin during the breeding season, which are based upon density estimates for the Northern Survey Area.
- Table 8: provides alternative annual collision risk mortality estimates for each species based upon JNCC/SNH seasons.
- Table 9: provides alternative seasonal collision risk mortality estimates for herring gull based upon JNCC/SNH seasons.
- Table 10: provides alternative seasonal collision risk mortality estimates for great black-backed gull based upon JNCC/SNH seasons.
- Table 11: provides alternative seasonal collision risk mortality estimates for kittiwake based upon JNCC/SNH seasons
- Table 12: provides alternative seasonal collision risk mortality estimates for arctic tern based upon JNCC/SNH seasons
- Appendix A provides density estimates for SNH/JNCC seasons based on survey effort within different strata.

All estimates of density and abundance for puffin been corrected for the presence of any unidentified auks that could potentially have been puffins, following the methodology set out in Appendix C of Caloo (2014a). However, with only 7 such sightings of unidentified auks across the whole study area during the whole year (5 on the water, 2 in flight) the effect of these corrections on the density and abundance estimates for puffin is either none or

negligible, depending the area surveyed, the season and whether the estimate is for birds on the water, birds in flight or both combined.

Across all tables:

- Densities are in units of nos/km².
- “est.” is an abbreviation of “estimate”.
- “cv” is an abbreviation of “coefficient of variation”.
- “df” is an abbreviation of “degrees of freedom”.
- “lcl” is an abbreviation of “lower confidence limit”.
- “ucl” is an abbreviation of “upper confidence limit”.
- “Max. est” is an abbreviation of “maximum estimate”, and
- “Max ucl” is an abbreviation of “maximum upper confidence limit”.

REFERENCES

Caloo. 2014a. Distance sampling analyses of year 1 ESAS survey results for the Hywind Scotland Pilot Park. Unpublished report from Caloo Ecological Services to Xodus Aurora. December 2014.

Caloo. 2014b. Collision risk modelling with respect to seabirds for the Hywind Scotland Pilot Park. Unpublished report from Caloo Ecological Services to Xodus Aurora. December 2014.

NRP 2014. Hywind Scotland Pilot Park Seabirds and Marine Mammals Technical Report.

Figure 1: Strata used in calculation of density and abundance estimates

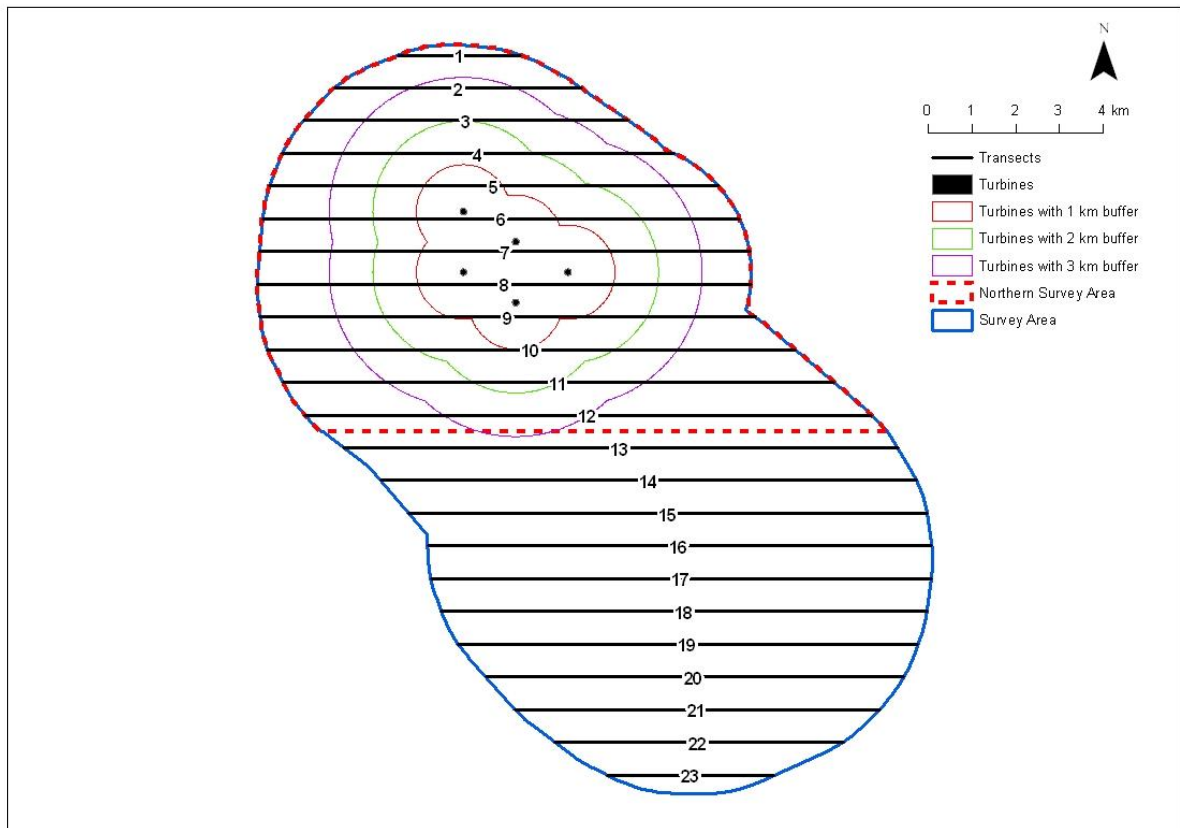


Table 1: Seasons for species as recommended by JNCC/SNH where these differ from those used in our assessment

Species	Breeding Season	Non-breeding season
Herring Gull	April-August	September-March
Great black-backed gull	April-August	September-March
Kittiwake	April-August	September-March
Arctic tern	May-August	September-April
Puffin	April-August	September-March

Table 2: Density estimates for JNCC/SNH seasons based on survey effort across the whole survey area.

Table 2a: Birds on water and in flight.

Species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	12	19	0.05	41%	14.9	0.03	0.10	0.38	0.97
Herring gull	Non-breeding	9	148	237	0.94	20%	28.6	0.67	1.31	3.14	6.57
Great black-backed gull	Breeding	11	8	11	0.03	59%	12.2	0.01	0.08	0.26	0.83
Great black-backed gull	Non-breeding	9	173	195	0.82	10%	109.9	0.69	0.97	2.45	3.29
Kittiwake	Breeding	11	371	2165	6.19	19%	17.2	4.48	8.56	43.55	70.64
Kittiwake	Non-breeding	9	44	54	0.21	20%	17.8	0.15	0.29	1.10	1.85
Arctic tern	Breeding	8	17	233	0.95	57%	11.2	0.37	2.45	7.40	19.51
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	855	1441	7.97	7%	48.7	7.08	8.97	39.63	46.53
Puffin	Non-breeding	9	133	263	1.60	12%	27.7	1.31	1.96	10.15	13.23

Table 2b: Birds on water

Species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	30	66	0.35	44%	14.6	0.17	0.74	2.41	6.10
Great black-backed gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Great black-backed gull	Non-breeding	9	90	98	0.50	14%	70.7	0.39	0.62	1.70	2.54
Kittiwake	Breeding	11	104	1444	4.27	25%	12.4	2.76	6.61	35.41	62.25
Kittiwake	Non-breeding	9	5	5	0.03	51%	25.8	0.02	0.08	0.12	0.55
Arctic tern	Breeding	8	9	210	0.87	62%	11.1	0.31	2.41	6.94	19.30
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	803	1359	7.75	7%	47.8	6.87	8.75	38.44	45.33
Puffin	Non-breeding	9	131	261	1.60	12%	27.7	1.30	1.96	10.15	13.23

Table 2c: Birds in flight

Species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	12	19	0.05	41%	14.9	0.03	0.10	0.38	0.97
Herring gull	Non-breeding	9	118	171	0.58	18%	34.0	0.43	0.79	1.54	2.96
Great black-backed gull	Breeding	11	8	11	0.03	59%	12.2	0.01	0.08	0.26	0.83
Great black-backed gull	Non-breeding	9	83	97	0.32	15%	39.4	0.25	0.42	0.75	1.24
Kittiwake	Breeding	11	267	721	1.92	24%	19.0	1.27	2.91	8.14	19.90
Kittiwake	Non-breeding	9	39	49	0.17	22%	12.6	0.12	0.25	1.10	1.85
Arctic tern	Breeding	8	8	23	0.08	57%	13.6	0.03	0.22	0.47	1.61
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	52	82	0.22	25%	51.0	0.15	0.33	1.19	2.17
Puffin	Non-breeding	9	2	2	0.01	72%	20.0	0.00	0.02	0.03	0.14

Table 3: Density estimates for puffins during the breeding season based on survey effort within the Northern Survey Area.

Subset	species	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
on water	Puffin	11	459	800	8.92	9%	18.6	7.68	10.36	50.37	59.85
in flight	Puffin	11	26	42	0.22	28%	6.8	0.13	0.37	1.37	3.26
combined	Puffin	11	485	842	9.14	8%	18.8	7.89	10.58	51.74	61.24

Table 4: Abundance estimates for the whole survey area, based upon survey effort across the whole survey area

Table 4a: Birds on water and in flight

Species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	9	4	17	65	165
Herring gull	Non-breeding	160	114	224	536	1,120
Great black-backed gull	Breeding	5	2	13	45	141
Great black-backed gull	Non-breeding	140	118	165	418	562
Kittiwake	Breeding	1,056	764	1,460	7,425	12,044
Kittiwake	Non-breeding	35	25	50	188	315
Arctic tern	Breeding	162	63	418	1,263	3,327
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	1,359	1,207	1,530	6,758	7,934
Puffin	Non-breeding	273	223	335	1,730	2,255

Table 4b: Birds on water

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	0	0	0	0	0
Herring gull	Non-breeding	60	29	126	411	1,040
Great black-backed gull	Breeding	0	0	0	0	0
Great black-backed gull	Non-breeding	84	67	106	290	433
Kittiwake	Breeding	728	470	1,127	6,037	10,613
Kittiwake	Non-breeding	6	3	13	20	94
Arctic tern	Breeding	148	53	411	1,183	3,290
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	1,321	1,171	1,492	6,554	7,728
Puffin	Non-breeding	272	222	333	1,730	2,255

Table 4c: Birds in flight

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	9	4	17	65	165
Herring gull	Non-breeding	99	73	135	263	504
Great black-backed gull	Breeding	5	2	13	45	141
Great black-backed gull	Non-breeding	55	43	71	128	211
Kittiwake	Breeding	328	217	497	1,387	3,393
Kittiwake	Non-breeding	29	20	43	188	315
Arctic tern	Breeding	14	6	37	80	275
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	37	25	56	204	370
Puffin	Non-breeding	1	0	3	5	24

Table 5: Abundance estimates for a 1 km buffer around the turbines, based upon density estimates for the whole survey area, apart from the estimates for puffin during the breeding season, which are based upon density estimates for the Northern Survey Area.

Table 5a: Birds on water and in flight

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	1	0	1	5	13
Herring gull	Non-breeding	12	9	17	41	86
Great black-backed gull	Breeding	0	0	1	3	11
Great black-backed gull	Non-breeding	11	9	13	32	43
Kittiwake	Breeding	81	58	112	568	922
Kittiwake	Non-breeding	3	2	4	14	24
Arctic tern	Breeding	12	5	32	97	255
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	119	103	138	675	799
Puffin	Non-breeding	21	17	26	132	173

Table 5b: Birds on water

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	0	0	0	0	0
Herring gull	Non-breeding	5	2	10	31	80
Great black-backed gull	Breeding	0	0	0	0	0
Great black-backed gull	Non-breeding	6	5	8	22	33
Kittiwake	Breeding	56	36	86	462	812
Kittiwake	Non-breeding	0	0	1	2	7
Arctic tern	Breeding	11	4	31	91	252
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	116	100	135	657	781
Puffin	Non-breeding	21	17	26	132	173

Table 5c: Birds in flight

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	1	0	1	5	13
Herring gull	Non-breeding	8	6	10	20	39
Great black-backed gull	Breeding	0	0	1	3	11
Great black-backed gull	Non-breeding	4	3	5	10	16
Kittiwake	Breeding	25	17	38	106	260
Kittiwake	Non-breeding	2	2	3	14	24
Arctic tern	Breeding	1	0	3	6	21
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	3	2	5	18	42
Puffin	Non-breeding	0	0	0	0	2

Table 6: Abundance estimates for a 2 km buffer around the turbines, based upon density estimates for the whole survey area, apart from the estimates for puffin during the breeding season, which are based upon density estimates for the Northern Survey Area.

Table 6a: Birds on water and in flight

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	2	1	3	11	29
Herring gull	Non-breeding	28	20	40	95	198
Great black-backed gull	Breeding	1	0	2	8	25
Great black-backed gull	Non-breeding	25	21	29	74	99
Kittiwake	Breeding	187	135	258	1,314	2,131
Kittiwake	Non-breeding	6	4	9	33	56
Arctic tern	Breeding	29	11	74	223	589
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	276	238	319	1,561	1,847
Puffin	Non-breeding	48	39	59	306	399

Table 6b: Birds on water

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	0	0	0	0	0
Herring gull	Non-breeding	11	5	22	73	184
Great black-backed gull	Breeding	0	0	0	0	0
Great black-backed gull	Non-breeding	15	12	19	51	77
Kittiwake	Breeding	129	83	199	1,068	1,878
Kittiwake	Non-breeding	1	0	2	3	17
Arctic tern	Breeding	26	9	73	209	582
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	269	232	312	1,519	1,805
Puffin	Non-breeding	48	39	59	306	399

Table 6c: Birds in flight

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	2	1	3	11	29
Herring gull	Non-breeding	18	13	24	47	89
Great black-backed gull	Breeding	1	0	2	8	25
Great black-backed gull	Non-breeding	10	8	13	23	37
Kittiwake	Breeding	58	38	88	245	600
Kittiwake	Non-breeding	5	4	8	33	56
Arctic tern	Breeding	3	1	6	14	49
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	7	4	11	41	98
Puffin	Non-breeding	0	0	1	1	4

Table 7: Abundance estimates for a 3 km buffer around the turbines, based upon density estimates for the whole survey area, apart from the estimates for puffin during the breeding season, which are based upon density estimates for the Northern Survey Area.

Table 7a: Birds on water and in flight

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	3	1	5	20	52
Herring gull	Non-breeding	50	36	70	168	351
Great black-backed gull	Breeding	2	1	4	14	44
Great black-backed gull	Non-breeding	44	37	52	131	176
Kittiwake	Breeding	331	239	457	2,324	3,770
Kittiwake	Non-breeding	11	8	16	59	99
Arctic tern	Breeding	51	20	131	395	1,042
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	488	421	564	2,762	3,269
Puffin	Non-breeding	86	70	105	542	706

Table 7b: Birds on water

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	0	0	0	0	0
Herring gull	Non-breeding	19	9	40	129	326
Great black-backed gull	Breeding	0	0	0	0	0
Great black-backed gull	Non-breeding	26	21	33	91	136
Kittiwake	Breeding	228	147	353	1,890	3,322
Kittiwake	Non-breeding	2	1	4	6	30
Arctic tern	Breeding	46	17	129	370	1,030
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	476	410	553	2,689	3,194
Puffin	Non-breeding	85	70	104	542	706

Table 7c: Birds in flight

species	season	Average number of birds present			Maximum number of birds present	
		est.	lcl	ucl	Max. Est	Max. ucl
Herring gull	Breeding	3	1	5	20	52
Herring gull	Non-breeding	31	23	42	82	158
Great black-backed gull	Breeding	2	1	4	14	44
Great black-backed gull	Non-breeding	17	13	22	40	66
Kittiwake	Breeding	103	68	155	434	1,062
Kittiwake	Non-breeding	9	6	14	59	99
Arctic tern	Breeding	4	2	11	25	86
Arctic tern	Non-breeding	0	0	0	0	0
Puffin	Breeding	12	7	20	73	174
Puffin	Non-breeding	0	0	1	2	7

Table 8: Alternative annual collision risk mortality estimates for each species based upon JNCC/SNH seasons

Species	Band option	Flight Height data	Collision Risk Model	% of flights at risk height (Q2r)	% of flights at risk height through rotor	% of all flights through rotor	% flights after dark	Total No of flights during rotor operation	No of flights through rotor	Average P. of collision during single transit	Predicted number of collisions under different avoidance rates				
											0%	95%	98%	99%	99.5%
Herring Gull	1	Site	Basic	40%	79%	32%	36%	81390	25697	6.5%	1665.3	83.3	33.3	16.7	8.3
	2	Generic	Basic	30%	79%	24%	36%	81390	19315	6.5%	1251.7	62.6	25.0	12.5	6.3
	3	Generic	Extended	30%	54%	16%	36%	81390	13320	4.1%	547.9	27.4	11.0	5.5	2.7
	4	Site	Extended	40%	42%	17%	36%	81390	13897	3.2%	441.8	22.1	8.8	4.4	2.2
Great black-backed gull	1	Site	Basic	38%	79%	30%	36%	48602	14601	6.7%	974.0	48.7	19.5	9.7	4.9
	2	Generic	Basic	31%	79%	24%	36%	48602	11753	6.7%	784.0	39.2	15.7	7.8	3.9
	3	Generic	Extended	31%	55%	17%	36%	48602	8210	4.4%	360.4	18.0	7.2	3.6	1.8
	4	Site	Extended	38%	47%	18%	36%	48602	8750	3.6%	318.5	15.9	6.4	3.2	1.6
Kittiwake	1	Site	Basic	15%	79%	12%	16%	245442	29862	5.6%	1668.0	83.4	33.4	16.7	8.3
	2	Generic	Basic	14%	79%	11%	16%	245442	26218	5.6%	1464.5	73.2	29.3	14.6	7.3
	3	Generic	Extended	14%	44%	6%	16%	245442	14729	2.5%	362.4	18.1	7.2	3.6	1.8
	4	Site	Extended	15%	39%	6%	16%	245442	14955	2.2%	327.1	16.4	6.5	3.3	1.6
Arctic tern	2	Generic	Basic	3%	79%	3%	0%	5771	155	5.6%	8.65	0.43	0.17	0.09	0.04
	3	Generic	Extended	3%	35%	1%	0%	5771	69	2.0%	1.41	0.07	0.03	0.01	0.01

Table 9: Alternative seasonal collision risk mortality estimates for herring gull based upon JNCC/SNH seasons

Season	Band option	Flight Height data	Collision Risk Model	Density estimate (no/km ²)	% flights after dark	Total No of flights during rotor operation	No of flights through rotor	P. of collision during single transit	Predicted number of collisions under different avoidance rates				
									0%	95%	98%	99%	99.5%
Breeding	1	Site	Basic	0.05	14%	5709	1802	6.3%	113.2	5.7	2.3	1.1	0.6
	2	Generic	Basic	0.05	14%	5709	1355	6.3%	85.1	4.3	1.7	0.9	0.4
	3	Generic	Extended	0.05	14%	5709	934	3.9%	36.5	1.8	0.7	0.4	0.2
	4	Site	Extended	0.05	14%	5709	975	3.0%	28.9	1.4	0.6	0.3	0.1
Non-breeding	1	Site	Basic	0.58	37%	75681	23895	6.5%	1552.1	77.6	31.0	15.5	7.8
	2	Generic	Basic	0.58	37%	75681	17960	6.5%	1166.6	58.3	23.3	11.7	5.8
	3	Generic	Extended	0.58	37%	75681	12385	4.1%	511.4	25.6	10.2	5.1	2.6
	4	Site	Extended	0.58	37%	75681	12922	3.2%	412.8	20.6	8.3	4.1	2.1

Table 10: Alternative seasonal collision risk mortality estimates for great black-backed gull based upon JNCC/SNH seasons

									Predicted number of collisions under different avoidance rates				
Season	Band option	Flight Height data	Collision Risk Model	Density estimate (no/km ²)	% flights after dark	Total No of flights during rotor operation	No of flights through rotor	P. of collision during single transit	0%	95%	98%	99%	99.5%
Breeding	1	Site	Basic	0.03	14%	3542	1064	6.5%	68.7	3.4	1.4	0.7	0.3
	2	Generic	Basic	0.03	14%	3542	857	6.5%	55.3	2.8	1.1	0.6	0.3
	3	Generic	Extended	0.03	14%	3542	598	4.2%	24.9	1.2	0.5	0.2	0.1
	4	Site	Extended	0.03	14%	3542	638	3.4%	21.8	1.1	0.4	0.2	0.1
Non-breeding	1	Site	Basic	0.32	37%	45060	13537	6.7%	905.3	45.3	18.1	9.1	4.5
	2	Generic	Basic	0.32	37%	45060	10896	6.7%	728.7	36.4	14.6	7.3	3.6
	3	Generic	Extended	0.32	37%	45060	7612	4.4%	335.5	16.8	6.7	3.4	1.7
	4	Site	Extended	0.32	37%	45060	8113	3.7%	296.7	14.8	5.9	3.0	1.5

Table 11: Alternative seasonal collision risk mortality estimates for kittiwake based upon JNCC/SNH seasons

Season	Band option	Flight Height data	Collision Risk Model	Density estimate (no/km ²)	% flights after dark	Total No of flights during rotor operation	No of flights through rotor	P. of collision during single transit	Predicted number of collisions under different avoidance rates				
									0%	95%	98%	99%	99.5%
Breeding	1	Site	Basic	1.92	14%	222566	27079	5.6%	1509.4	75.5	30.2	15.1	7.5
	2	Generic	Basic	1.92	14%	222566	23775	5.6%	1325.2	66.3	26.5	13.3	6.6
	3	Generic	Extended	1.92	14%	222566	13356	2.4%	326.8	16.3	6.5	3.3	1.6
	4	Site	Extended	1.92	14%	222566	13561	2.2%	294.8	14.7	5.9	2.9	1.5
Non-breeding	1	Site	Basic	0.17	37%	22876	2783	5.7%	158.6	7.9	3.2	1.6	0.8
	2	Generic	Basic	0.17	37%	22876	2444	5.7%	139.3	7.0	2.8	1.4	0.7
	3	Generic	Extended	0.17	37%	22876	1373	2.6%	35.5	1.8	0.7	0.4	0.2
	4	Site	Extended	0.17	37%	22876	1394	2.3%	32.3	1.6	0.6	0.3	0.2

Table 12: Alternative seasonal collision risk mortality estimates for Arctic tern based upon JNCC/SNH seasons

									Predicted number of collisions under different avoidance rates				
Season	Band option	Flight Height data	Collision Risk Model	Density estimate (no/km ²)	% flights after dark	Total No of flights during rotor operation	No of flights through rotor	P. of collision during single transit	0%	95%	98%	99%	99.5%
Breeding	2	Generic	Basic	0.084	0%	5771	155	5.6%	8.65	0.43	0.17	0.09	0.04
	3	Generic	Extended	0.084	0%	5771	69	2.0%	1.41	0.07	0.03	0.01	0.01

Appendix A: Density estimates for JNCC/SNH seasons based on survey effort within different strata.

Table A.1: Density estimates based on survey effort within a 1 km buffer around the turbines.

Table A.1a: Birds on water and in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	16	46	3.26	48%	1.3	0.49	21.64	25.37	234.84
Great black-backed gull	Breeding	11	1	1	0.04	86%	1.0	0.00	4.49	0.44	49.36
Great black-backed gull	Non-breeding	9	23	25	1.51	22%	2.3	0.84	2.72	6.16	208.03
Kittiwake	Breeding	11	26	58	2.60	50%	1.1	0.23	29.91	12.61	3281.63
Kittiwake	Non-breeding	9	2	2	0.08	71%	4.0	0.02	0.31	0.35	4.20
Arctic tern	Breeding	8	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	82	130	9.33	14%	5.4	7.10	12.27	53.52	220.96
Puffin	Non-breeding	9	10	23	1.50	25%	3.1	0.84	2.67	11.44	78.93

Table A.1b: Birds on water

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	10	35	2.83	55%	1.3	0.31	25.97	24.94	239.41
Great black-backed gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Great black-backed gull	Non-breeding	9	13	14	1.07	29%	1.7	0.42	2.76	5.73	208.03
Kittiwake	Breeding	11	8	36	1.78	72%	1.0	0.04	76.26	12.17	3709.48
Kittiwake	Non-breeding	9	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Breeding	8	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	79	127	9.22	14%	5.3	6.99	12.16	53.15	220.96
Puffin	Non-breeding	9	10	23	1.50	25%	3.1	0.84	2.67	11.44	78.93

Table A.1c: Birds in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	6	11	0.44	45%	2.3	0.14	1.37	3.15	36.70
Great black-backed gull	Breeding	11	1	1	0.04	86%	1.0	0.00	4.49	0.44	49.36
Great black-backed gull	Non-breeding	9	10	11	0.44	30%	5.4	0.24	0.79	1.42	36.70
Kittiwake	Breeding	11	18	22	0.83	31%	4.1	0.43	1.58	2.23	221.62
Kittiwake	Non-breeding	9	2	2	0.08	71%	4.0	0.02	0.31	0.35	4.20
Arctic tern	Breeding	8	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	3	3	0.11	68%	1.8	0.02	0.79	0.86	83.24
Puffin	Non-breeding	9	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00

Table A.2: Density estimates based on survey effort within a 2 km buffer around the turbines.

Table A.2a: Birds on water and in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	2	2	0.03	71%	6.0	0.01	0.10	0.17	1.23
Herring gull	Non-breeding	9	41	94	2.31	35%	5.3	1.17	4.54	12.65	36.70
Great black-backed gull	Breeding	11	1	1	0.02	100%	3.0	0.00	0.11	0.17	1.20
Great black-backed gull	Non-breeding	9	45	48	1.22	17%	18.6	0.91	1.62	5.80	8.53
Kittiwake	Breeding	11	72	256	4.20	38%	5.4	2.05	8.63	16.49	99.40
Kittiwake	Non-breeding	9	3	3	0.06	56%	9.0	0.02	0.14	0.17	1.17
Arctic tern	Breeding	8	2	27	0.72	91%	3.0	0.12	4.45	5.75	35.62
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	174	308	9.71	12%	10.9	7.87	11.98	57.48	77.76
Puffin	Non-breeding	9	29	59	1.93	15%	8.1	1.46	2.55	12.82	18.20

Table A.2b: Birds on water

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	15	46	1.39	53%	3.9	0.47	4.08	12.00	36.65
Great black-backed gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Great black-backed gull	Non-breeding	9	30	32	0.92	21%	14.8	0.64	1.31	5.48	8.19
Kittiwake	Breeding	11	16	135	2.38	59%	3.6	0.72	7.89	16.14	100.20
Kittiwake	Non-breeding	9	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Breeding	8	2	27	0.72	91%	3.0	0.12	4.45	5.75	35.62
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	166	292	9.46	12%	10.5	7.63	11.73	55.74	76.24
Puffin	Non-breeding	9	28	58	1.91	15%	8.1	1.44	2.53	12.82	18.20

Table A.2c: Birds in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	2	2	0.03	71%	6.0	0.01	0.10	0.17	1.23
Herring gull	Non-breeding	9	26	48	0.92	36%	4.0	0.44	1.91	3.22	18.78
Great black-backed gull	Breeding	11	1	1	0.02	100%	3.0	0.00	0.11	0.17	1.20
Great black-backed gull	Non-breeding	9	15	16	0.30	24%	10.2	0.20	0.46	0.86	2.45
Kittiwake	Breeding	11	56	121	1.82	40%	3.3	0.76	4.35	11.50	48.79
Kittiwake	Non-breeding	9	3	3	0.06	56%	9.0	0.02	0.14	0.17	1.17
Arctic tern	Breeding	8	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	8	16	0.25	64%	4.5	0.07	0.84	1.74	10.81
Puffin	Non-breeding	9	1	1	0.02	97%	3.0	0.00	0.12	0.16	1.08

Table A.3: Density estimates based on survey effort within a 3 km buffer around the turbines.

Table A.3a: Birds on water and in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	2	2	0.02	71%	10.0	0.01	0.05	0.10	0.51
Herring gull	Non-breeding	9	62	117	1.57	33%	9.0	0.87	2.85	7.78	20.83
Great black-backed gull	Breeding	11	3	3	0.03	72%	6.0	0.01	0.09	0.19	1.08
Great black-backed gull	Non-breeding	9	66	71	0.96	13%	32.4	0.77	1.20	3.37	5.15
Kittiwake	Breeding	11	127	516	4.69	29%	7.4	2.76	7.96	19.22	68.33
Kittiwake	Non-breeding	9	8	10	0.11	30%	13.4	0.06	0.18	0.56	1.14
Arctic tern	Breeding	8	6	41	0.62	56%	4.1	0.21	1.85	4.74	14.78
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	297	521	9.30	10%	14.3	7.78	11.10	50.46	60.13
Puffin	Non-breeding	9	44	83	1.62	17%	10.3	1.19	2.18	9.38	14.34

Table A.3b: Birds on water

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	16	47	0.80	59%	6.2	0.28	2.29	6.96	20.58
Great black-backed gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Great black-backed gull	Non-breeding	9	37	39	0.61	20%	25.6	0.44	0.86	3.09	4.89
Kittiwake	Breeding	11	26	318	3.02	40%	5.0	1.39	6.56	18.64	68.51
Kittiwake	Non-breeding	9	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Breeding	8	4	39	0.59	58%	4.1	0.19	1.85	4.74	14.78
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	283	495	9.07	10%	14.1	7.57	10.88	49.13	58.77
Puffin	Non-breeding	9	43	82	1.60	17%	10.3	1.18	2.17	9.38	14.34

Table A.3c: Birds in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	2	2	0.02	71%	10.0	0.01	0.05	0.10	0.51
Herring gull	Non-breeding	9	46	70	0.77	30%	7.0	0.44	1.34	2.29	9.87
Great black-backed gull	Breeding	11	3	3	0.03	72%	6.0	0.01	0.09	0.19	1.08
Great black-backed gull	Non-breeding	9	29	32	0.35	13%	18.2	0.28	0.43	0.76	1.44
Kittiwake	Breeding	11	101	198	1.67	36%	5.5	0.83	3.32	9.43	32.88
Kittiwake	Non-breeding	9	8	10	0.11	30%	13.4	0.06	0.18	0.56	1.14
Arctic tern	Breeding	8	2	2	0.02	95%	5.0	0.00	0.12	0.19	0.94
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	14	26	0.22	37%	6.0	0.11	0.45	1.33	4.45
Puffin	Non-breeding	9	1	1	0.01	96%	5.0	0.00	0.05	0.09	0.47

Table A.4: Density estimates based on survey effort within the Northern Survey Area.

Table A.4a: Birds on water and in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	5	6	0.03	49%	12.3	0.01	0.07	0.18	0.67
Herring gull	Non-breeding	9	91	154	1.20	28%	10.9	0.74	1.97	5.38	12.97
Great black-backed gull	Breeding	11	5	5	0.03	83%	5.6	0.01	0.11	0.24	1.26
Great black-backed gull	Non-breeding	9	103	115	0.93	12%	38.5	0.76	1.13	2.96	4.42
Kittiwake	Breeding	11	208	1007	5.64	25%	10.4	3.62	8.79	30.28	69.20
Kittiwake	Non-breeding	9	12	14	0.09	23%	15.4	0.06	0.14	0.54	0.90
Arctic tern	Breeding	8	8	44	0.40	57%	5.2	0.14	1.16	2.94	9.23
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	485	842	9.14	8%	18.8	7.89	10.58	51.74	61.24
Puffin	Non-breeding	9	66	112	1.39	13%	15.3	1.10	1.75	7.76	10.71

Table A.4b: Birds on water

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	20	53	0.53	54%	6.3	0.20	1.41	4.41	12.56
Great black-backed gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Great black-backed gull	Non-breeding	9	56	58	0.55	16%	27.1	0.41	0.72	2.59	4.06
Kittiwake	Breeding	11	50	609	3.59	35%	6.8	1.88	6.83	22.56	64.93
Kittiwake	Non-breeding	9	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Arctic tern	Breeding	8	4	39	0.37	62%	5.1	0.12	1.15	2.94	9.23
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	459	800	8.92	9%	18.6	7.68	10.36	50.37	59.85
Puffin	Non-breeding	9	64	110	1.38	13%	15.3	1.09	1.74	7.76	10.71

Table A.4c: Birds in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	5	6	0.03	49%	12.3	0.01	0.07	0.18	0.67
Herring gull	Non-breeding	9	71	101	0.68	26%	11.3	0.43	1.06	1.73	6.14
Great black-backed gull	Breeding	11	5	5	0.03	83%	5.6	0.01	0.11	0.24	1.26
Great black-backed gull	Non-breeding	9	47	57	0.38	17%	11.8	0.28	0.52	0.77	2.30
Kittiwake	Breeding	11	158	398	2.05	31%	10.3	1.18	3.57	7.72	26.86
Kittiwake	Non-breeding	9	12	14	0.09	23%	15.4	0.06	0.14	0.54	0.90
Arctic tern	Breeding	8	4	5	0.03	78%	5.0	0.01	0.14	0.27	1.08
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	26	42	0.22	28%	6.8	0.13	0.37	1.37	3.26
Puffin	Non-breeding	9	2	2	0.01	75%	10.0	0.00	0.04	0.05	0.32

Table A.5: Density estimates based on survey effort within the whole survey area.

Table A.5a: Birds on water and in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	12	19	0.05	41%	14.9	0.03	0.10	0.38	0.97
Herring gull	Non-breeding	9	148	237	0.94	20%	28.6	0.67	1.31	3.14	6.57
Great black-backed gull	Breeding	11	8	11	0.03	59%	12.2	0.01	0.08	0.26	0.83
Great black-backed gull	Non-breeding	9	173	195	0.82	10%	109.9	0.69	0.97	2.45	3.29
Kittiwake	Breeding	11	371	2165	6.19	19%	17.2	4.48	8.56	43.55	70.64
Kittiwake	Non-breeding	9	44	54	0.21	20%	17.8	0.15	0.29	1.10	1.85
Arctic tern	Breeding	8	17	233	0.95	57%	11.2	0.37	2.45	7.40	19.51
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	855	1441	7.97	7%	48.7	7.08	8.97	39.63	46.53
Puffin	Non-breeding	9	133	263	1.60	12%	27.7	1.31	1.96	10.15	13.23

Table A.5b: Birds on water

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Herring gull	Non-breeding	9	30	66	0.35	44%	14.6	0.17	0.74	2.41	6.10
Great black-backed gull	Breeding	11	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Great black-backed gull	Non-breeding	9	90	98	0.50	14%	70.7	0.39	0.62	1.70	2.54
Kittiwake	Breeding	11	104	1444	4.27	25%	12.4	2.76	6.61	35.41	62.25
Kittiwake	Non-breeding	9	5	5	0.03	51%	25.8	0.02	0.08	0.12	0.55
Arctic tern	Breeding	8	9	210	0.87	62%	11.1	0.31	2.41	6.94	19.30
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	803	1359	7.75	7%	47.8	6.87	8.75	38.44	45.33
Puffin	Non-breeding	9	131	261	1.60	12%	27.7	1.30	1.96	10.15	13.23

Table A.5c: Birds in flight

species	season	Sample size			Average density of birds present					Maximum density of birds present	
		surveys	sightings	individual animals	estimate	cv	df	lcl	ucl	Maximum estimate	Maximum ucl
Herring gull	Breeding	11	12	19	0.05	41%	14.9	0.03	0.10	0.38	0.97
Herring gull	Non-breeding	9	118	171	0.58	18%	34.0	0.43	0.79	1.54	2.96
Great black-backed gull	Breeding	11	8	11	0.03	59%	12.2	0.01	0.08	0.26	0.83
Great black-backed gull	Non-breeding	9	83	97	0.32	15%	39.4	0.25	0.42	0.75	1.24
Kittiwake	Breeding	11	267	721	1.92	24%	19.0	1.27	2.91	8.14	19.90
Kittiwake	Non-breeding	9	39	49	0.17	22%	12.6	0.12	0.25	1.10	1.85
Arctic tern	Breeding	8	8	23	0.08	57%	13.6	0.03	0.22	0.47	1.61
Arctic tern	Non-breeding	12	0	0	0.00	0%	0.0	0.00	0.00	0.00	0.00
Puffin	Breeding	11	52	82	0.22	25%	51.0	0.15	0.33	1.19	2.17
Puffin	Non-breeding	9	2	2	0.01	72%	20.0	0.00	0.02	0.03	0.14