Hornsea Project Three
Offshore Wind Farm

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Offshore Wind Farm

Environmental Statement:
Volume 5, Annex 5.4 – Data Hierarchy Report

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Hornsea 3
Offshore Wind Farm

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Environmental Impact Assessment

Environmental Statement

Volume 5

Annex 5.4 – Data Hierarchy Report

Liability

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Glossary

Term	Definition
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report.
Former Hornsea Zone	The Hornsea Zone was one of nine offshore wind generation zones around the UK coast identified by The Crown Estate (TCE) during its third round of offshore wind licensing. In March 2016, the Hornsea Zone Development Agreement was terminated and project specific agreements, Agreement for Leases (AfLs), were agreed with The Crown Estate for Hornsea Project One, Hornsea Project Two, Hornsea Project Three and Hornsea Project Four. The Hornsea Zone has therefore been dissolved and is referred to throughout the Hornsea Project Three Scoping Report as the former Hornsea Zone.
Hornsea Project One offshore wind farm	The first offshore wind farm project within the former Hornsea Zone. It has a maximum capacity of 1.2 gigawatts (GW) or 1,200 MW and includes all necessary offshore and onshore infrastructure required to connect to the existing National Grid substation located at North Killingholme, North Lincolnshire. Referred to as Project One throughout the Environmental Statement.
Hornsea Project Three offshore wind farm	The third offshore wind farm project within the former Hornsea Zone. It has a maximum capacity of 2.4 GW (2,400 MW) and includes offshore and onshore infrastructure to connect to the existing National Grid substation located at Norwich Main, Norfolk. Referred to as Hornsea Three throughout the Environmental Statement.
Hornsea Project Two offshore wind farm	The second offshore wind farm project within the former Hornsea Zone. It has a maximum capacity of 1.8 GW (1,800 MW) and includes offshore and onshore infrastructure to connect to the existing National Grid substation located at North Killingholme, North Lincolnshire. Referred to as Project Two throughout the Environmental Statement.
Planning Inspectorate (PINS)	The executive agency of the Department for Communities and Local Government responsible for operating the planning process for NSIPs.

Acronyms

Acronym	Description
CRM	Collision Risk Modelling
CV	Coefficient of variance
DAS	Digital Aerial Survey
EIA	Environmental Impact Assessment
EWG	Expert Working Group
GBMs	Generalized Boosted Regression Models
GLMs	Generalized Linear Models
SNCBs	Statutory Nature Conservation Bodies
SPA	Special Protected Area
SST	Sea Surface Temperature
ZDA	Hornsea Zonal Development Area, the Former Hornsea Zone

Units

Unit	Description
Birds/km^2	Number of birds per square kilometre (bird density)

1. Introduction

1.1.1.1 This annex presents information which provides a method and evidence for an approach to selecting which density or population estimates of birds should be used for assessing the potential impact of the proposed Hornsea Project Three offshore wind farm (hereafter referred to as Hornsea Three). It provides an extension to the analysis carried out by HiDef of the boat-based and digital aerial survey data.

1.1.1.2 There is a recommendation from Natural England to provide a minimum of two years of contemporary bird density or population data to inform an Environmental Impact Assessment (EIA) for submission to the Planning Inspectorate. This is recommended so that inter-annual variability in seabird abundance within a site can be taken in to account in the assessment. A full two years of Digital Video Aerial Survey (DAS) data was not available in time for inclusion in the EIA for the proposed submission date.

1.1.1.3 Multiple estimates of bird density have been calculated from different survey data sources: boat-based data collected for the adjacent Hornsea Project One and Hornsea Project Two array areas, and Hornsea Zonal Development Area (ZDA) between March 2010 and February 2013, modelled predictions of density for the period from April 2015 to March 2016 using boat-based data for Hornsea Three and the Hornsea Zone, and DAS for Hornsea Threefrom April 2016 to November 2017.

1.1.1.4 After presentation of these data at a meeting of the Expert Working Group (EWG) for the Hornsea Three Project on 5 June 2017, questions remained about which of these abundance data were most suitable for use in the assessment of potential impact for Hornsea Three. Questions revolved around how comparable bird density estimates were between boat-based survey data and DAS data; the amount and location of survey coverage obtained in Hornsea Three in boat-based surveys; the effect of inter-annual variation on the bird density; and the ability of modelling methods to resolve these questions.

1.1.1.5 This report proposes a hierarchy of the most suitable bird density data to be used, with reasons, and a decision-making process for deciding when lower-ranked data should be used in preference over higher ranked data.

2. Methods and approach

2.1.1.1 The goal when selecting data for use in the assessment is to capture the naturally occurring inter-annual variability in monthly bird density and where mixed data sources are used, as is inevitable in the case at Hornsea Three, to ensure that the reasons for selecting a particular data set are transparent and use criteria based upon objective assessment of data quality.

2.1.1.2 Guidelines issued by the Statutory Nature Conservation Bodies (SNCBs) require different data to be used when considering collision risk modelling and for assessment of potential displacement impacts. For collision risk modelling (CRM) using the Band (2012) model, the guidelines are clear in requiring that the mean flying bird density is used based on the number of years with suitable data. For displacement impact assessment, a more precautionary measure of total bird population is used (SNCB 2017) in which in every season, the peak population estimate is selected for each year, and the mean of those annual seasonal peak populations is calculated. In determining a suitable approach, this is framed differently by different advice from SNCBs on the preferred approach.

2.2 Sources of data: digital aerial survey

2.2.1.1 Digital aerial survey data were collected monthly between April 2016 to November 2017 and has been processed up to November 2017 for submission of the EIA. This means that in some summer months, two years of DAS data will be available for bird density estimates in the EIA while in migration and winter months only one year of DAS will be available for the assessment. DAS data cover at least 10% of Hornsea Three plus 4km buffer and even coverage of the area is obtained irrespective of the season.

2.3 Sources of data: boat-based survey

2.3.1.1 Boat-based survey data were collected on a monthly basis between March 2010 and February 2013, but targeted at the Hornsea Project One and Hornsea Project Two array areas with a 4 km buffer around them. When possible, particularly in the first year of the programme, these surveys were extended to theformer Hornsea Zone with a 10 km buffer around it, when reasonably systematic coverage of Hornsea Three and buffers was obtained. All of the boat-based data will be older than the recommended age for data used in an EIA (five years) (SNH, 2014) at the time of submission in Quarter 2 of 2018. It should be noted that this advice is in relation to onshore wind farm assessments, where the ecology and life history of the species being assessed is fundamentally different from seabirds at sea; however, the scoping opinion by Marine Scotland for the planned Inch Cape Offshore Wind Farm determined that five to seven year-old data was acceptable as baseline data with allowance for the consequent uncertainty. In months of good coverage, over 5% of Hornsea Three with 4 km buffer (1,229.97 km^2) was covered, but in months of poor coverage, short transects on the periphery of this study site totalling less than 1% coverage were obtained. The best coverage tended to be obtained in the summer months, as is typical of boat-based survey campaigns. The precision of density and population estimates for Hornsea Three tended to be low as a consequence mainly of the relatively low number of transects used as samples.

2.3.1.2 There is little data availability from other studies to demonstrate the comparability of boat-based bird density estimates and DAS estimates; most attempts tend not to be able to deal with the differences in survey speed which results in the two different platforms sampling different areas of the sea at different times, thus leading to different abundances, likely caused by these sampling differences. Webb and Hawkins (2013) found that abundance estimates from the two platforms tended to be similar under perfect surveyconditions for the boat-based survey, with slightly higher abundance estimates for diving species such as auks (Alcidae) from the boat-based surveys, most likely attributable to there being no correction for availability bias in the DAS data for these species. However, under suitable but less optimal conditions for the boat-based survey there were higher abundance estimates for all species from the digital video platform. Although it should be noted that the sample size for this comparison was small and most differences were not statistically significant.

2.4 Sources of data: modelled predictions from boat-based survey

2.4.1.1 As a potential method for comparing density estimates between the boat-based and digital video aerial survey, it was proposed by the Ornithology EWG that data modelling could be used to predict the density of key species in the Hornsea Three study area and the Hornsea ZDA study area for the same month and year for which there are DAS data. Generalized Linear (GLMs) and Generalized Boosted Regression Models (GBMs) were constructed using non-static co-variates such as sea surface temperature (SST), salinity, phytoplankton, year, month, and season as predictive variables. Overall, the predictions worked best for the most abundant species in the summer months in the Hornsea Three study area. The predicted density in the Hornsea ZDA was more robust with greater explained variance (R^2) for the significant terms or the terms used in the models than for Hornsea Three, and it was possible to use the more robust GBMs for most species in the ZDA than Hornsea Three. Much of this difference came down to the quantity and quality of the density data from the boat-based surveys; there were many missing values for the density estimates in Hornsea Three and low or spatially biased effort used to derive the density estimates in some of the remaining months which could mean that some of the bird densities being matched to the values for the covariates in the models were unreliable. Another important factor was the predictive power of the available covariates; while care was taken to select the best available of these, it is likely that the causes of seasonal and inter-annual variation in bird density at Hornsea Three are highly complex and may include, for example, inter- and intra-specific behavioural reasons, a wider range of prey indicators, or more particularly, prey conditions in other parts of the North Sea, especially those close to the natal or home nesting site. While that might be predictable in the summer months, this is considerably more difficult to assign at other times of the year. Both modelling methods produced surprisingly narrow confidence intervals for the predicted density estimates, it is unclear what might have caused these, but not including variance from the co-variates used in the models would certainly have underestimated the variance of the predicted abundance; a common omission in predictive models. The modelled predictions for bird density in both the Hornsea ZDA and Hornsea Three study area were for the same time period as when the digital aerial surveys were carried out. If predicted density and population size for Hornsea Three were to be used to represent the inter-annual variability in these values, then the models would need to be re-run using predictor co-variates for a different year from when the aerial surveys were carried out.

2.4.1.2 The empirical boat-based density estimates for each of the key species (but excluding little gull *Hydrocoloeus minutus* and herring gull *Larus argentatus*) in Hornsea Three, in the Hornsea ZDA, when compared with the predicted density for these areas for 2016/17 and the empirical DAS data for 2106/17 during the winter months shows how predicted density, in particular in Hornsea Three, differs more from the DAS density estimates than the empirical boat-based survey data results differ from the DAS density estimates. These are presented in Appendix A of this report.

2.5 Data hierarchy

2.5.1.1 As part of the process for deciding which are the best available bird density data to use in an EIA, it was necessary to rank each data type according to their suitability. This is done in Table 1.1, below, with an explanation for the ranking.

2.5.1.1 Overall, is considered that year is less important than location when assessing the potential impact of a development. Given that the overall objective behind selecting a second monthly estimate of density is objectively to reflect the inter-annual variability in seabird abundance data for a location, it becomes more important that the source chosen reflects the location rather than the time, considering the relatively short period over which data are being sourced (eight years). Kober et al. (2010), when assessing potential sites for consideration as offshore seabird Special Protection Areas (SPA), found that seabird density hotspots tended to persist between years relative to the surrounding coldspots. Webb et al. (2014) found in an analysis of the age of offshore seabird density data for use in assessment of seabird sensitivity to oil pollution, that abundance cycles and trends tended to occur over the space of 15 years, which is twice as long as the oldest data under consideration here. Consequently, we have ranked older empirical data more highly than modelled predictions for a more recent 12-month period.

2.5.1.2 There is an exception to this judgement because we have ranked the modelled predictions of density in Hornsea Three as being of lower value than the modelled predictions for Hornsea ZDA. This is because the HOW03 predictions were based upon a smaller bird density dataset where coverage was not necessarily even across the Hornsea Three study area. Consequently, the more robust GBMs could not be used at all in this area, explained variance (R^2 values) for co-variates that were significant in the preferred models were usually low, and there was often wide divergence, particularly in the key non-breeding months from both the DAS data for the key species as well as the older boat-based data for both Hornsea Three and Hornsea ZDA. By giving these data the lowest rank, we are, in effect, recommending that these data are not used.

2.6 Hierarchical prioritisation method

2.6.1.1 When given a hierarchy of different data types, there will be circumstances in which it is not possible to use the highest ranked data because of lack of availability or because the data are unsuitable for other valid reasons. The proposed methods are given below in Table 1.2.

2.6.1.2 Firstly, it is proposed that if two years of DAS data are available in a given month, then any mean density will be based on these measurements as highest-ranking data according to Table 1.1. When only one year of DAS data is available, then it is proposed that a comparison will be made between the single DAS density estimate for each month and the equivalent empirical boat-based density estimates for each year separately. If the single DAS density estimate does not differ significantly from the range of estimates obtained from the recent boat-based survey estimates for the same region, then a single year of DAS, and associated 95% confidence intervals, is considered sufficient for use in collision risk modelling. We propose that the rule of average 50% overlap of 95% confidence intervals should be used as a measure of significance . While mindful of Cumming and Fidler's (2005) note of potential shortcomings of this approach, this is sufficiently robust for these purposes given that these shortcomings relate to the type of precision required for hypothesis testing. If the confidence intervals of any comparisons do not overlap sufficiently for any given comparison, then if the mean estimate for the DAS falls between the different estimates for that month, then this will be considered sufficient for use of a single year for that month. If there are no empirical boat-based density estimates for the Hornsea Three project area for comparison with the DAS density estimate, then the DAS density should instead be compared with the Hornsea ZDA data instead.

2.6.1.3 If the DAS density estimate does not fall within the range of variability of either the Hornsea Three project area of the Hornsea ZDA, then a mean should be calculated using all years for which there are sufficient data (see Table 1.2). Reasons for rejecting the use of empirical estimates of bird density are relatively simple and are based upon clear data quality issues. There are two stages for selecting density data from empirical boat-based surveys:

- Selection of individual month of survey data in any one year for all species based on whether the survey data meet a minimum standard of coverage and survey effort; and
- Selection of the dataset as a whole, based on whether there are sufficient data points to calculate a mean seasonal peak population for displacement assessment or mean flying density for collision risk modelling.

2.6.1.4 Two should be the minimum sample size for calculating mean density of flying birds in Hornsea Three, including when DAS and boat-based data are used together. There may potentially be a sample size of four if one year of DAS and three years of empirical boat-based data are available.

Table 1.1: Ranking of different types of monthly estimates and predictions of bird density with reasons for ranking.

Data type	Ranking	Reason
Digital Aerial Survey Data	1	• Robust data collection method obtained within two years prior to EIA submission date; • Targeted surveys with even coverage of HOW03 site; • Over 10% coverage of site; • Robust analysis of data with realistic confidence intervals; • No reliance on co-variates with potentially poor predictive power.
Monthly boat-based density or population estimates for Hornsea Three only	2	• Robust data collection method but obtained more than five years prior to EIA submission date; • Data collected from HOW03 study area; • Low (0.5 – 5.0% coverage) and uneven survey effort in some months; • Robust data analysis with realistic confidence intervals; • No reliance on co-variates with potentially poor predictive power; and • Assumed comparability with DAS data.
Monthly boat-based density or population estimates for Hornsea ZDA	3	• Robust data collection method but obtained more than five years prior to EIA submission date; • Based on data from wider geographical area than HOW03 site; • Low (<0.5 – 9.0% coverage) and uneven survey effort in some months; • Robust data analysis with realistic confidence intervals; • No reliance on co-variates with potentially poor predictive power; and • Assumed comparability with DAS data.
Predicted density from modelled boat-based data for Hornsea ZDA	4	• Prediction for the same year/month combinations as DAS; • Based on robust data collection methods; • Based on data from wider geographical area than HOW03 site; • Based on low (<0.5 – 9.0% coverage) and uneven survey effort in some months; • Robust analysis but with perhaps unrealistically narrow confidence intervals; and • Co-variates used not always best predictors of inter-annual and seasonal changes in abundance.
Predicted density from modelled boat-based data for Hornsea Three	5	• Prediction for the same year/month combinations as DAS; • Based on robust data collection methods; • Targeted at HOW03 site; • Based on low (0.5 – 5.0% coverage) and uneven survey effort in some months; • Robust analysis but with perhaps unrealistically narrow confidence intervals; • Sometimes widely divergent abundance estimates from DAS data in comparable months; and • Co-variates used not always best predictors of inter-annual and seasonal changes in abundance.

Table 1.2: Density data type and reasons for rejecting its use in a hierarchical framework for data use in EIA.

Data type and hierarchy	Decision-making process for using lower ranked data for any given month
Digital Aerial Survey Data	• If two years of data available, use both of these for all purposes; • For CRM only, if only one year of data available, if the confidence limits for the density estimate overlap the confidence limits for each of the equivalent Hornsea Three density boat-based estimates, or if the DAS mean density estimate falls between the equivalent boat-based mean densities, then use just the single year of DAS density estimate for that month; • For CRM, if there are no boat-based density estimates for Hornsea Three, compare with Hornsea ZDA boat-based density estimates instead; • For CRM, if the DAS density falls outside the variation in the equivalent boat-based density estimates, calculate a monthly mean and 95% CIs for the second year using equivalent suitable boat-based survey data based on the descriptions in the next boxes; and • For displacement, in months without two years of DAS data, proceed to next available data source.
Monthly boat-based density or population estimates for HOW03 only	• Monthly density must be based on month/years when at least four long transects are present; • Their location must not be spatially biased either entirely in the east or west half **†;** • Calculate the mean value across all years of suitable data for birds in flight for CRM; and • Select the peak value in each season in which at least 50% of months have sufficient data, and calculate the annual mean of birds on the water *and* in flight for displacement assessment.
Monthly boat-based density or population estimates for Hornsea ZDA	• Monthly density must be based on month/years when at least 15 transects are present and over 100 km^2 has been achieved; • Calculate the mean value across all years of suitable data for birds in flight; • Population estimates need to be calculated from the density for the Hornsea ZDA and converted to a population estimate by multiplying up by the surface area of the Hornsea Three site; • Select the peak value in each season in which at least 50% of months have sufficient data, and calculate the annual mean of birds on the water *and* in flight for displacement assessment.
Predicted density from modelled boat-based data for Hornsea ZDA	Should not be required
Predicted density from modelled boat-based data for HOW03	Should not be used
† As an examplein May 2012 contains five long transects which are biased to the West, but extend across the East-West half-way line therefore could be included (although there are already two years of DAS for this month and would be used as a priority). Effort in October 2012 consists of only two transect in the Hornsea Three area (with no buffer) and all of these occur in the western half of the study area, therefore estimates for this month will not be used. Effort in January 2013 is based on four long transects which are centred mainly in the middle or eastern half of Hornsea Three	

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2.6.1.5 For selecting monthly density or population estimates in any year for Hornsea Three or 2km buffers, we consider a minimum number of long transects should have been surveyed in the area in any month and year combination for the density or population estimate to be used in the assessments. These transects extend across the project site from north to south and give a more representative sample of bird density than the shorter transects used for calculating density in neighbouring Hornsea One and Hornsea Two which penetrate the buffers for Hornsea Three. A minimum of four long transects will reduce the total transect length provided by the short transects to less than 25%; we consider this to be sufficient to represent a suitable north to south coverage of the site. A suitable east to west coverage of the site can be achieved by rejecting month/year density or population estimates in which all the long transects occur either in the eastern or the western half of Hornsea Three.

2.6.1.6 The coverage for monthly density or population estimates in any year based on Hornsea ZDA empirical boat-based data, is generally better, although it is usually centred on the Hornsea One and Hornsea Two study areas. However, in one month, December 2011, the survey effort consisted of only six short transects and only 28.66 km^2 of data, whereas in all other year/month combinations the number of transects and survey effort is considerably higher and always covering at least part of Hornsea Three and its buffers. For this reason, we recommend that December 2011 empirical data from Hornsea ZDA is not used in any assessments,

2.6.1.7 When calculating seasonal maxima for calculating the mean of peak population estimates in displacement impact assessment, a peak population estimate may not be representative of the true peak if there are many months in the season in which there is insufficient survey coverage, in other words, the peak could have occurred in a month in which there was insufficient survey to include the data from that month. It is recommended that a minimum number of months with sufficient survey coverage should be set before the whole season's maximum can be used in the calculation of the mean of peak. We have used 50% of months with sufficient coverage within a single season as the minimum.

2.7 Calculation of coefficient of variation and confidence intervals for mean density

2.7.1.1 The coefficient of variation of the pooled density (CV_t) estimates can be calculated from:

$$CV_t = \sqrt{\frac{(CV_1{}^2 \times N_1{}^2) + (CV_2{}^2 \times N_2{}^2)}{N_t{}^2}}$$

Where CV_1 = CV for the stratum 1, CV_2 is the CV for stratum 2, N_1 is the density stratum 1, N_2 is the density stratum 2 and N_t is the pooled density for both strata.

2.7.1.2 The lower and upper confidence limits for the pooled density can be re-calculated by calculating a standard deviation as the product of mean density and CV. The standard error is calculated as the standard deviation divided by the square root of the number of pooled estimates (n). The lower and upper 95% confidence limits are taken to be the pooled estimated plus or minus the product of the standard error and 1.96, and assumes a normal distribution around the mean.

2.8 Worked examples

2.8.1.1 Two examples are given to show how the mean density or population size would be calculated using the above principles, one for displacement using northern gannet (hereafter referred to as gannet *Morus bassanus*) and another for collision risk modelling also using gannet. These examples are just restricted to calculating the actual mean rather than the associated lower and upper confidence limits.

2.8.2 Worked example, calculating peak mean population estimate for displacement of gannet in Hornsea Three with 2 km buffer

2.8.2.1 The first step is to complete a matrix of population estimates available from digital aerial surveys and for displacement analysis (see Table 1.3), identify the different seasons from which the seasonal maximum occurred (see Table 1.4).

Table 1.3: Worked example of calculation of mean of peak population size. Stage 1, addition of DAS population estimates. Highlighted populations are used for calculation of mean. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	928	240	307	799	159	180	277	146	936	22	147	113
DAS 17/18	58	179	103	881	1,738	1,215	1691	143	None	None	None	None

2.8.2.2 This reveals that the density can already be calculated for the breeding season when August data are available. Alternative data will be required to calculate the peak mean density for migration – spring period.

Table 1.4: Worked example of calculation of mean of peak population size. Stage 2, calculating mean of seasonal peaks from DAS. Highlighted populations are used for calculation of mean. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	928	240	307	799	159	180	277	146	936	22	147	113
DAS 17/18	58	179	103	881	1,738	1,215	1,691	143	None	None	None	None
Mean of peak	**1,333**					**984**						

2.8.2.3 For the months in which no DAS data are available, it is necessary to view the survey coverage from boat-based surveys in each year month combination to assess whether sufficient coverage has been obtained. These show that sufficient coverage for the months with one year of DAS data were obtained in Hornsea Three with 2km buffer in December 2010; January, March 2011; March 2012 and January and March 2013. These densities can be entered in the reworked table below (see Table 1.5).

2.8.2.4 Several gaps remain for calculating a mean of peaks, but in spite of this, these can still be calculated now in the 2010/11 and the 2012/13 seasons as shown above, but not in the 2011/12 season where fewer than 50% of the months had suitable coverage for a seasonal peak to be used to calculate the mean.

Table 1.5: Worked example of calculation of mean of peak population size. Stage 3, addition of boat-based population estimates and calculation of mean of seasonal peaks. Highlighted populations are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	928	240	307	799	159	180	277	146	936	22	147	113
DAS 17/18	58	179	103	881	1,738	1,215	1,691	143	None	None	None	None
HOW03 + 2km Boat 10/11	NR	NR	NR	NR	NR	NR	NR	NR	93	167	NVD	10
HOW03 + 2km Boat 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NVD	NVD	136
HOW03 + 2km Boat 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NVD	19	NVD	114
Mean of peak	**1,333**					**984**			**406**			

2.8.3 Worked example, calculating mean density for collision risk modelling of gannet in Hornsea Three with no buffer

2.8.3.1 As above, the first step is to compile a matrix of density estimates available from digital aerial survey using the flying only density of gannets in Hornsea Three with no buffer in the same way as for calculating mean of seasonal peak density for displacement impact assessment. The same procedure will be needed also for calculating the means using lower and upper confidence limits.

Table 1.6: Worked example of calculation of mean density. Stage 1, addition of DAS. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	0.17	0.00	0.09	0.17	0.03	0.10	0.08	0.07	0.59	0.02	0.00	0.08
DAS 17/18	0.02	0.03	0.02	0.33	0.66	0.22	0.77	0.17	None	None	None	None

2.8.3.2 It is possible now to calculate mean density for CRM in April, May, June, July, August, September, October and November using data calculated from flights (see Table 1.7). The next step is to choose the best data for use in the other months. This is done by inspecting the comparison of densities in Figure 2.1.

Table 1.7: Worked example of calculation of mean density. Stage 2, calculation of mean density from DAS. Density figures in bold are used for calculation of mean. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**0.17**	**0.00**	**0.09**	**0.17**	**0.03**	**0.10**	**0.08**	**0.07**	0.59	0.02	0.00	0.08
DAS 17/18	**0.02**	**0.03**	**0.02**	**0.33**	**0.66**	**0.22**	**0.77**	**0.17**	None	None	None	None
Mean density	**0.09**	**0.02**	**0.05**	**0.25**	**0.34**	**0.16**	**0.43**	**0.12**				

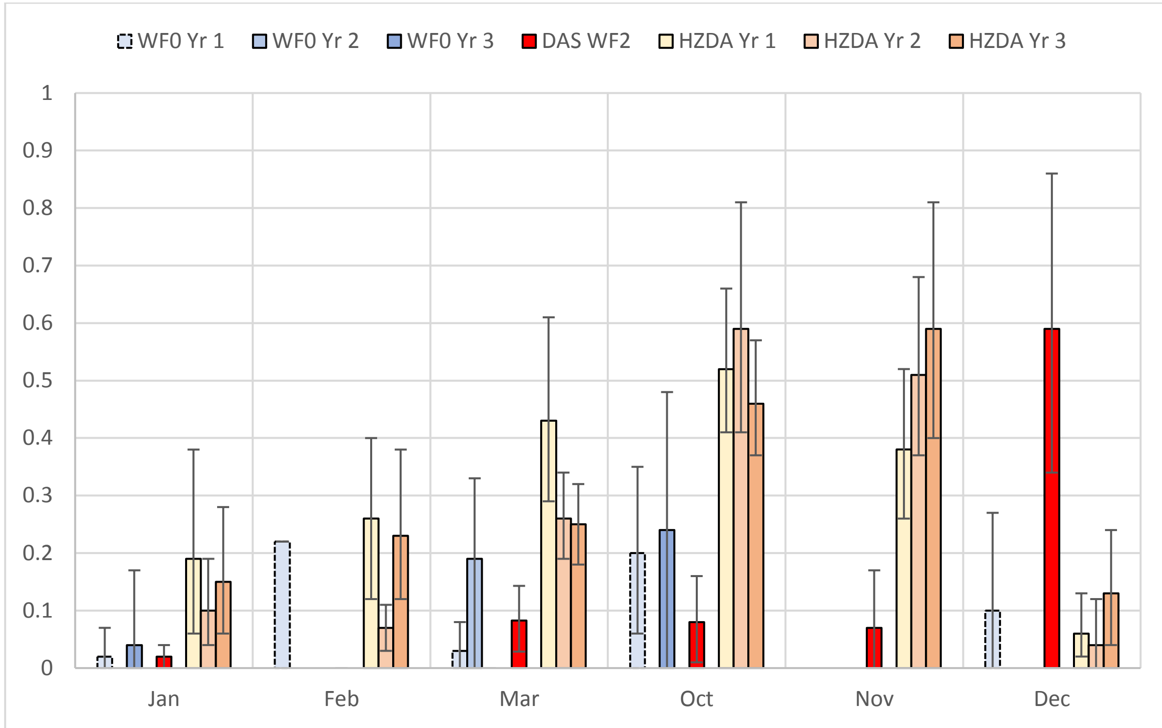

Figure 2.1: Comparison of gannet flying density in Hornsea Three from boat-based and digital aerial surveys.

2.8.3.3 Figure 2.1 shows that the confidence intervals for flying gannets in the DAS and the boat-based surveys in Hornsea Three overlap comfortably in January and March. Because of insufficient survey transects in Year 1 February boat surveys, it was not possible to calculate confidence intervals and the density estimate did not match the 0 density from the DAS data. If it had been possible to calculate confidence intervals for February and there had been no overlap, it would have been necessary to assess the suitability of this single boat-based data point, at which point, the survey coverage in February 2011 would have been deemed insufficient. In December the DAS and boat-based confidence intervals do not overlap at all for the one year of boat-based data. On this basis, it is acceptable to use a single year of data from the DAS for January and March now, and this is filled in in Table 1.8. The single year of boat-based data in Hornsea Three in December 2010 can be used to make the second year of density data.

Table 1.8: Worked example of calculation of mean density. Stage 3, addition of boat-based density for Hornsea Three where required. Density figures in bold are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**0.17**	**0.00**	**0.09**	**0.17**	**0.03**	**0.10**	**0.08**	**0.07**	**0.59**	**0.02**	0.00	**0.08**
DAS 17/18	**0.02**	**0.03**	**0.02**	**0.33**	**0.66**	**0.22**	**0.77**	**0.17**	None	None	None	None
Boat HOW03 10 /11	NR	NR	NR	NR	NR	NR	NR	NR	**0.10**	NR	NVD	NR
Boat HOW03 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
Boat HOW03 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
Mean density	**0.10**	**0.02**	**0.06**	**0.25**	**0.35**	**0.16**	**0.43**	**0.12**	**0.34**	**0.02**		**0.08**

2.8.3.4 The penultimate step is to populate the density table (Table 1.9) with data from the Hornsea ZDA for the months of February, and December. All three years will be required to calculate the mean density from the boat-based data where possible. Assessment of the suitability of coverage requires at least 100 km2 of boat-based effort and 15 transects. Insufficient coverage was obtained in December Year 2, so these data do not contribute to the mean density.

Table 1.9: Worked example of calculation of mean density. Stage 4, addition of boat-based density for Hornsea ZDA where required. Density figures in bold are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**0.17**	**0.00**	**0.09**	**0.17**	**0.03**	**0.10**	**0.08**	**0.07**	**0.59**	**0.02**	**0.00**	**0.08**
DAS 17/18	**0.02**	**0.03**	**0.02**	**0.33**	**0.66**	**0.22**	**0.77**	**0.17**	None	None	None	None
Boat HOW03 10 /11	NR	NR	NR	NR	NR	NR	NR	NR	**0.10**	NR	NVD	NR
Boat HOW03 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
Boat HOW03 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.26**	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.07**	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.23**	NR
Mean	**0.09**	**0.02**	**0.05**	**0.25**	**0.34**	**0.16**	**0.43**	**0.12**	**0.34**	**0.02**	**0.14**	**0.08**

2.8.3.5 The final step is to calculate the lower and upper 95% confidence limits to the mean (pooled) density estimate, derived from the CV for each of the contributing density estimates via a pooled CV, standard deviation and standard error. This is demonstrated in Table 1.10.

Table 1.10 Worked example of calculation of mean density. Stage5, calculation of lower and upper confidence intervals for mean based on pooled CV and pooled SE calculations. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**0.17**	**0.00**	**0.09**	**0.17**	**0.03**	**0.10**	**0.08**	**0.07**	**0.59**	**0.02**	**0.00**	**0.08**
DAS 17/18	**0.02**	**0.03**	**0.02**	**0.33**	**0.66**	**0.22**	**0.77**	**0.17**	None	None	None	None
Boat HOW03 10 /11	NR	NR	NR	NR	NR	NR	NR	NR	**0.10**	NR	NVD	NR
Boat HOW03 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
Boat HOW03 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.26**	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.07**	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.23**	NR
Mean	**0.09**	**0.02**	**0.05**	**0.25**	**0.34**	**0.16**	**0.43**	**0.12**	**0.34**	**0.02**	**0.14**	**0.08**
Pooled CV	**0.306**	**0.600**	**0.450**	**0.247**	**0.302**	**0.267**	**0.189**	**0.289**	**0.220**	**0.899**	**0.987**	**0.345**
Pooled SE	**0.020**	**0.007**	**0.017**	**0.044**	**0.074**	**0.030**	**0.057**	**0.017**	**0.053**	**0.010**	**0.098**	**0.020**
Lower 95% CI	**0.05**	**0.00**	**0.02**	**0.16**	**0.20**	**0.10**	**0.31**	**0.08**	**0.24**	**0.00**	**0.00**	**0.03**
Upper 95% CI	**0.13**	**0.03**	**0.09**	**0.34**	**0.49**	**0.22**	**0.54**	**0.15**	**0.45**	**0.04**	**0.33**	**0.12**

3. Species accounts

3.1.1.1 The following species accounts give the results of the above analysis when applied to the key species for displacement analysis and for collision risk modelling.

3.2 Northern fulmar *Fulmarus glacialis* population estimates

Table 1.11: Population size of northern fulmar in Hornsea Three + 2km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 2km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	642	91	1146	1,375	0	1,096	262	273	778	211	69	242
DAS 17/18	87	438	196	46	1,470	394	857	432				
HOW03 + 2km 10/11	446	3,187	728	498	2788	1,272	426		527	589	429	57
HOW03 + 2km 11/12	737	1,008	1,255	808	532							232
HOW03 + 2km 12/13	459	773	1,404	3,840	590					207		200
HZDA + 10km 10/11	194	1,698	695	354	898	605	324	307	319	488	206	406
HZDA + 10km 11/12	208	1,036	1,135	525	291	475	345	24		242	169	373
HZDA + 10km 12/13	758	5,476	2,649	769	232	436	208	131	142	140	74	218

Table 1.12: Mean of seasonal peak population size for northern fulmar in Hornsea Three + 2km buffer. Highlighted populations are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	642	91	1,146	1,375	0	1,096	262	273	778	211	69	242
DAS 17/18	87	438	196	46	1,470	394	857	432	None	None	None	None
HOW03 + 2km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	527	589	429	57
HOW03 + 2km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NVD	NVD	232
HOW03 + 2km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NVD	207	NVD	200
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Seasonal mean of peaks	**1,423**					**977**		**352**	**525**			

3.3 Northern gannet *Morus bassanus* densitites

Table 1.13: Density (number/km^2) of northern gannet in Hornsea Three + 0km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 0km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	0.17	0.00	0.09	0.17	0.03	0.10	0.08	0.07	0.59	0.02	0.00	0.08
DAS 17/18	0.02	0.03	0.02	0.33	0.66	0.22	0.77	0.17	None	None	None	None
HOW03 + 0km 10/11	0.17	0.00	0.10	0.02	0.50	0.24	0.20		0.10	0.02		0.03
HOW03 + 0km 11/12	0.00	0.05	0.12	0.18	0.02							0.19
HOW03 + 0km 12/13	0.00	0.00	0.02	0.18	0.52		0.24			0.04		0.00
HZDA + 10km 10/11	0.14	0.04	0.03	0.04	0.28	0.19	0.52	0.38	0.06	0.19	0.26	0.43
HZDA + 10km 11/12	0.04	0.04	0.07	0.28	0.11	0.17	0.59	0.51	0.04	0.10	0.07	0.26
HZDA + 10km 12/13	0.17	0.16	0.09	0.32	0.32	0.30	0.46	0.59	0.13	0.15	0.23	0.25

Table 1.14: Monthly mean flying density for northern gannet in Hornsea Three without buffer. Densities in bold are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**0.17**	**0.00**	**0.09**	**0.17**	**0.03**	**0.10**	**0.08**	**0.07**	**0.59**	**0.02**	**0.00**	**0.08**
DAS 17/18	**0.02**	**0.03**	**0.02**	**0.33**	**0.66**	**0.22**	**0.77**	**0.17**	None	None	None	None
HOW03 + 0km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	**0.10**	NR	NVD	NR
HOW03 + 0km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
HOW03 + 0km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NVD	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.26**	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.07**	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	**0.23**	NR
Mean	**0.09**	**0.02**	**0.05**	**0.25**	**0.34**	**0.16**	**0.43**	**0.12**	**0.34**	**0.02**	**0.14**	**0.08**
Lower 95% CI	**0.05**	**0.00**	**0.02**	**0.16**	**0.20**	**0.10**	**0.31**	**0.08**	**0.24**	**0.00**	**0.00**	**0.03**
Upper 95% CI	**0.13**	**0.03**	**0.09**	**0.34**	**0.49**	**0.22**	**0.54**	**0.15**	**0.45**	**0.04**	**0.33**	**0.12**

3.4 Gannet population estimates

Table 1.15: Population size of northern gannet in Hornsea Three + 2km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 2km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	928	240	307	799	159	180	277	146	936	22	147	113
DAS 17/18	58	179	103	881	1,738	1,215	1,691	143	None	None	None	None
HOW03 + 2km 10/11	168	42	87	132	2,172	570	1,028		93	167		10
HOW03 + 2km 11/12	128	63	201	200	93							136
HOW03 + 2km 12/13	238	200	110	377	1,694					19		115
HZDA+ 10km 10/11	297	63	126	133	719	590	1,080	716	147	265	449	647
HZDA + 10km 11/12	162	95	273	499	304	512	1,719	1,597		121	99	377
HZDA + 10km 12/13	512	461	382	680	651	742	1,303	841	192	194	262	440

Table 1.16: Mean of seasonal peak population size for northern gannet in Hornsea Three + 2km buffer. Highlighted populations are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	928	240	307	799	159	180	277	146	936	22	147	113
DAS 17/18	58	179	103	881	1,738	1,215	1,691	143	None	None	None	None
HOW03 + 2km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	93	167	NVD	10
HOW03 + 2km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NVD	NVD	136
HOW03 + 2km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NVD	19	NVD	114
HZDA+ 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Seasonal mean of peaks	**1,333**					**984**			**406**			

3.5 Atlantic puffin *Fratercula arctica* population estimates

Table 1.17: Population size of Atlantic puffin in Hornsea Three + 2km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 2km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	214	288	14	14	0	13	0	0	13	0	0	52
DAS 17/18	0	219	0	38	0	39	35	26	None	None	None	None
HOW03 + 2km 10/11	99	829	237	0	0	29	411		118	0		86
HOW03 + 2km 11/12	191	38	71	0	33							312
HOW03 + 2km 12/13	794	0	0	172	676					284		422
HZDA + 10km 10/11	809	673	1,404	54	241	944	2,056	1,193	605	702	410	398
HZDA + 10km 11/12	473	135	278	457	4,166	2,084	1,029	2,487		215	618	425
HZDA + 10km 12/13	817	794	318	647	2,196	2,827	451	891	1,091	1,005	901	1,030

Table 1.18: Mean of seasonal peak population size for Atlantic puffin in Hornsea Three + 2km buffer. Highlighted populations are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	214	288	14	14	0	13	0	0	13	0	0	52
DAS 17/18	0	219	0	38	0	39	40	26	None	None	None	None
HOW03 + 2km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 2km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 2km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Seasonal mean of peaks		**253**			**127**							

3.6 Razorbill *Alca torda* population estimates

Table 1.19: Population size of razorbill in Hornsea Three + 2km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 2km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	563	336	678	281	0	54	466	4,382	3,080	237	677	1,442
DAS 17/18	582	198	93	383	276	185	3,575	2,916	None	None	None	None
HOW03 + 2km 10/11	1,068	160	629	105	0	795	10,697		4,184	740		283
HOW03 + 2km 11/12	1,013	128	1,301	209	0							1,791
HOW03 + 2km 12/13	1,827	205	316	1,223	793					413		1,527
HZDA + 10km 10/11	3,035	488	760	5,166	4,020	11,448	9,051	2,025	4,089	1,341	1,277	2,228
HZDA + 10km 11/12	2,881	479	1,648	3,912	10,682	10,007	2,260	1,570		1,393	1,263	2,369
HZDA + 10km 12/13	2,798	1,887	2,090	3,455	5,150	12,472	213	77	69	482	812	2,831

Table 1.20: Mean of seasonal peak population size for razorbill in Hornsea Three + 2km buffer. Highlighted populations are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	563	336	678	281	0	54	466	4,382	3,080	237	677	1,442
DAS 17/18	582	198	93	383	276	185	3,575	2,916	None	None	None	None
HOW03 + 2km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	740	NVD	283
HOW03 + 2km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NVD	1,791
HOW03 + 2km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	413	NVD	1,527
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Seasonal mean of peaks	**630**				**2,020**			**3,649**		**1,236**		

3.7 Common guillemot *Uria aalge* population estimates

Table 1.21: Population size of common guillemot in Hornsea Three + 2km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 2km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	5,120	5,838	15,017	14,657	10,096	12,312	5,492	14,228	16,655	926	3,315	7,630
DAS 17/18	5,633	7,652	1,281	11,731	13,531	15,981	17,517	18,888	None	None	None	None
HOW03 + 2km 10/11	3,543	4,495	4,498	9,521	15,631	11,601	27,410		5,725	3,733		824
HOW03 + 2km 11/12	10,675	4,318	9,850	10,230	4,569							3,103
HOW03 + 2km 12/13	11,719	3,483	6,222	21,791	19,422					8,552		3,438
HZDA + 10km 10/11	5,326	3,649	4,411	13,579	20,499	29,866	24,897	11,697	8,742	4,302	4,353	1,878
HZDA + 10km 11/12	6,715	3,894	7,081	15,343	20,932	17,624	7,308	1,559		1,907	2,957	8,755
HZDA + 10km 12/13	10,658	9,974	10,177	10,210	16,745	29,820	4,450	1,704	2,850	2,583	5,293	5,989

Table 1.22: Mean of seasonal peak population size forcommon guillemot in Hornsea Three + 2km buffer. Highlighted populations are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	5,120	5,838	15,017	14,657	10,096	12,312	5,492	14,228	16,655	926	3,315	7,630
DAS 17/18	5,633	7,652	1,281	11,731	13,531	15,981	17,517	18,888	None	None	None	None
HOW03 + 2km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 2km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 2km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Seasonal mean of peaks	**13,374**				**17,772**							

3.8 Black-legged kittiwake *Rissa tridactyla* densities

Table 1.23: Density (number/km²) of black-legged kittiwake in Hornsea Three + 0km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 0km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	2.73	1.44	0.31	2.58	0.25	0.91	0.10	0.50	1.95	0.47	0.18	1.34
DAS 17/18	0.22	0.86	0.36	1.23	0.95	1.42	0.52	1.13	None	None	None	None
HOW03 + 0km 10/11	0.11	0.00	0.38	0.02	0.51	0.22	1.42		0.46	0.20	0.44	0.15
HOW03 + 0km 11/12	0.14	0.06	1.18	0.21	0.10							0.71
HOW03 + 0km 12/13	0.82	0.00	0.36	0.61	1.27					0.07		0.27
HZDA + 10km 10/11	0.22	0.11	0.48	1.09	1.02	0.74	0.50	1.42	0.41	0.27	0.66	0.42
HZDA + 10km 11/12	0.25	0.30	0.83	1.47	0.34	1.10	0.32	0.43		0.21	0.24	0.39
HZDA + 10km 12/13	1.05	0.98	1.19	1.49	1.16	1.01	0.41	0.64	0.29	0.27	0.18	0.42

Table 1.24: Monthly mean flying density for black-legged kittiwake in Hornsea Three without buffer. Densities in bold are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**2.73**	**1.44**	**0.31**	**2.58**	**0.25**	**0.91**	**0.10**	**0.50**	**1.95**	**0.47**	**0.18**	**1.34**
DAS 17/18	**0.22**	**0.86**	**0.36**	**1.23**	**0.95**	**1.42**	**0.52**	**0.52**	None	None	None	None
HOW03 + 0km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	**0.46**	NR	NR	NR
HOW03 + 0km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NR	NR
HOW03 + 0km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NVD	NR	NR	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Mean	**1.47**	**1.15**	**0.34**	**1.91**	**0.60**	**1.17**	**0.31**	**0.51**	**1.21**	**0.47**	**0.18**	**1.34**
Lower 95% CI	**0.95**	**0.76**	**0.22**	**1.15**	**0.45**	**0.69**	**0.23**	**0.41**	**0.81**	**0.27**	**0.06**	**0.69**
Upper 95% CI	**2.00**	**1.54**	**0.45**	**2.66**	**0.75**	**1.65**	**0.39**	**0.60**	**1.60**	**0.61**	**0.40**	**1.90**

3.9 Lesser black-backed gull *Larus fuscus* densities

Table 1.25: Density (number/km²) of lesser black-backed gull in Hornsea Three + 0km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 0km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	0.00	0.02	0.34	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DAS 17/18	0.04	0.00	0.09	0.15	0.08	0.00	0.00	0.00	None	None	None	None
HOW03 + 0km 10/11	0.26	0.00	0.04	0.03	0.25	0.03	0.00		0.00	0.00		0.02
HOW03 + 0km 11/12	0.34	0.31	0.26	0.00	0.00							0.04
HOW03 + 0km 12/13	0.13	0.04	0.02	0.22	0.02					0.00		0.00
HZDA + 10km 10/11	0.07	0.07	0.07	0.22	0.19	0.01	0.00	0.00	0.02	0.00	0.00	0.01
HZDA + 10km 11/12	0.05	0.15	0.08	0.03	0.03	0.04	0.00	0.00		0.01	0.00	0.01
HZDA + 10km 12/13	0.08	0.04	0.03	0.05	0.06	0.04	0.00	0.02	0.00	0.00	0.00	0.03

Table 1.26: Monthly mean flying density for lesser black-backed gull in Hornsea Three without buffer. Densities in bold are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**0.00**	**0.02**	**0.34**	**0.12**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
DAS 17/18	**0.04**	**0.00**	**0.09**	**0.15**	**0.08**	**0.00**	**0.00**	**0.00**	None	None	None	None
HOW03 + 0km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 0km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 0km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Mean	**0.02**	**0.01**	**0.21**	**0.14**	**0.04**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Lower 95% CI	**0.00**	**0.00**	**0.09**	**0.03**	**0.08**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Upper 95% CI	**0.04**	**0.02**	**0.34**	**0.24**	**0.08**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

3.10 Great black-backed gull *Larus marinus* densities

Table 1.27: Density (number/km²) of great black-backed gull in Hornsea Three + 0km buffer derived from digital aerial survey (DAS), boat-based survey data for Hornsea Three + 0km buffer and boat-based survey data for Hornsea ZDA. None = no data collected.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	0.02	0.00	0.04	0.08	0.00	0.04	0.03	0.20	0.46	0.13	0.04	0.03
DAS 17/18	0.00	0.00	0.00	0.41	0.05	0.15	0.13	0.10	None	None	None	None
HOW03 + 0km 10/11	0.07	0.00	0.07	0.00	0.27	0.82	0.27		0.19	0.11		0.27
HOW03 + 0km 11/12	0.11	0.17	0.19	0.07	0.06							0.45
HOW03 + 0km 12/13	0.00	0.04	0.00	0.00	0.05					0.24		0.02
HZDA + 10km 10/11	0.04	0.01	0.01	0.02	0.08	0.23	0.15	0.12	0.23	0.27	0.17	0.14
HZDA + 10km 11/12	0.07	0.06	0.03	0.04	0.02	0.40	0.11	0.24		0.09	0.11	0.17
HZDA + 10km 12/13	0.10	0.05	0.03	0.01	0.07	0.08	0.16	0.29	0.32	0.16	0.15	0.08

Table 1.28: Monthly mean flying density for great black-backed gull in Hornsea Three without buffer. Densities in bold are used for calculation of mean. None = no data collected, NR = not required, NVD = no valid data.

Data Source	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DAS 16/17	**0.02**	**0.00**	**0.04**	**0.08**	**0.00**	**0.04**	**0.03**	**0.20**	**0.46**	**0.13**	**0.04**	**0.03**
DAS 17/18	**0.00**	**0.00**	**0.00**	**0.41**	**0.05**	**0.15**	**0.13**	**0.10**	None	None	None	None
HOW03 + 0km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 0km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HOW03 + 0km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 10/11	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 11/12	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
HZDA + 10km 12/13	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Mean	**0.01**	**0.00**	**0.02**	**0.25**	**0.02**	**0.09**	**0.08**	**0.15**	**0.46**	**0.13**	**0.04**	**0.03**
Lower 95% CI	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.12**	**0.27**	**0.03**	**0.00**	**0.00**
Upper 95% CI	**0.02**	**0.00**	**0.04**	**0.49**	**0.04**	**0.18**	**0.12**	**0.18**	**0.60**	**0.20**	**0.07**	**0.06**

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Appendix A Comparison of predicted total density of key seabird species with empirical density estimates

A.1.1.1 The following graphs compare the predicted density of nine key species in Hornsea Three with 4km buffer and in Hornsea ZDA with 10km buffer for the period of April 2016 to February 2017 with the equivalent empirical data from digital aerial surveys for Hornsea Three + 2km buffer and the empirical boat-based density estimates for Hornsea Three + 2km buffer in three 12-month period from March 2010 to February 2013 (years 1, 2 and 3 respectively) and for Hornsea Zone + 10km buffer for years 1, 2 and 3).

A.1.1.2 The eight key species are northern fulmar *fulmarus glacialis*, northern gannet *Morus bassanus*, Atlantic puffin *Fratercula arctica*, razorbill *Alca torda*, common guillemot *Uria aalge*, black-legged kittiwake *Rissa tridactyla*, lesser black-backed gull *Larus fuscus*, and great black-backed gull *L. marinus*. These are presented in Figure A.1 to Figure A.8.

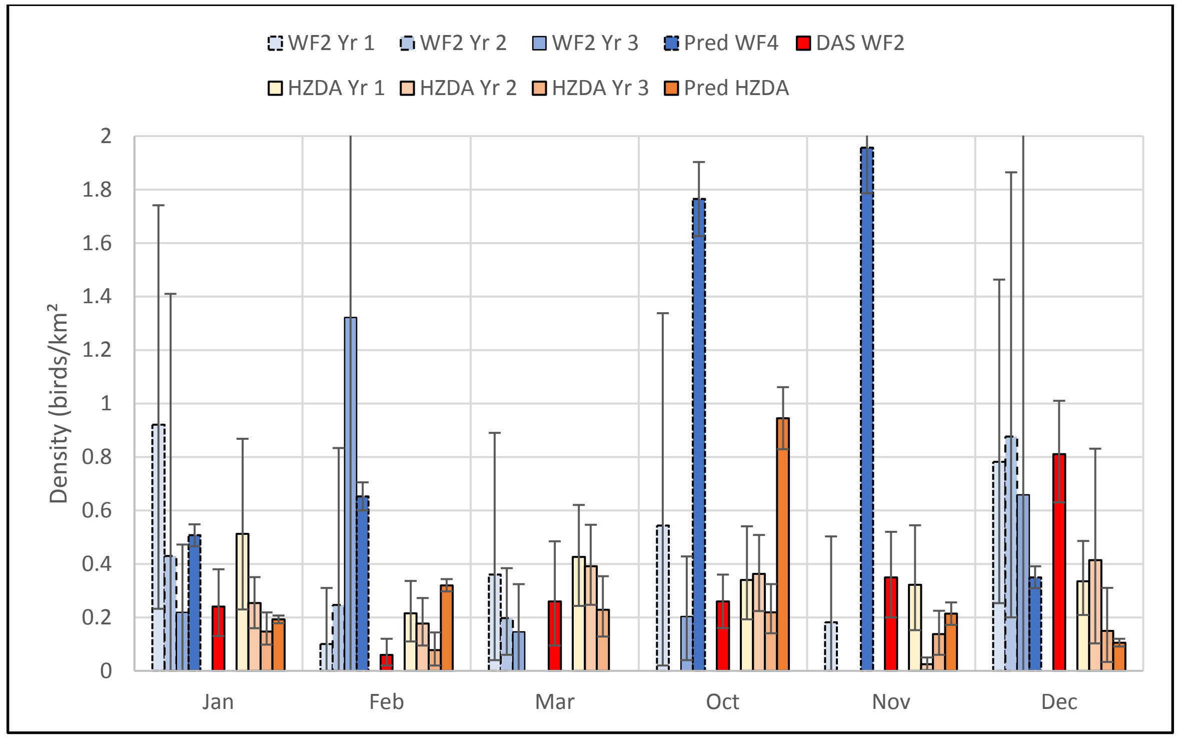

Figure A.1: Comparison of predicted density of northern fulmar in Hornsea Three project area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.

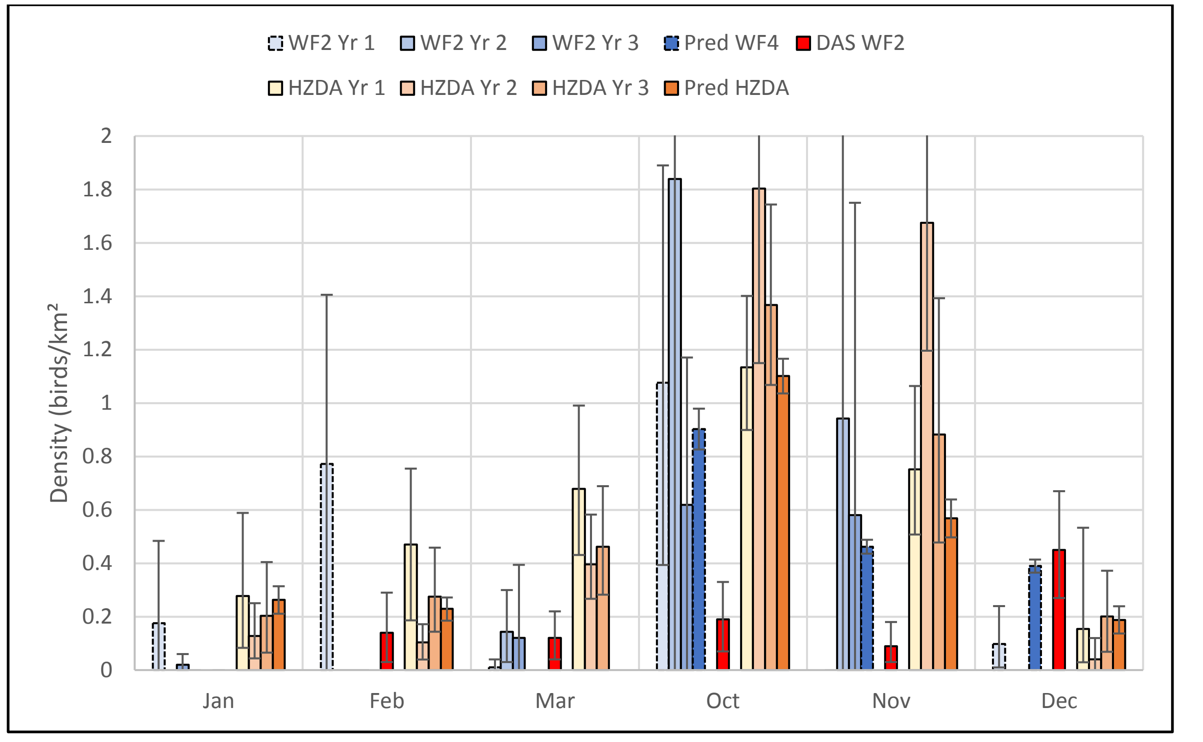

Figure A.2: Comparison of predicted density of northern gannet in Hornsea Threeproject area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.

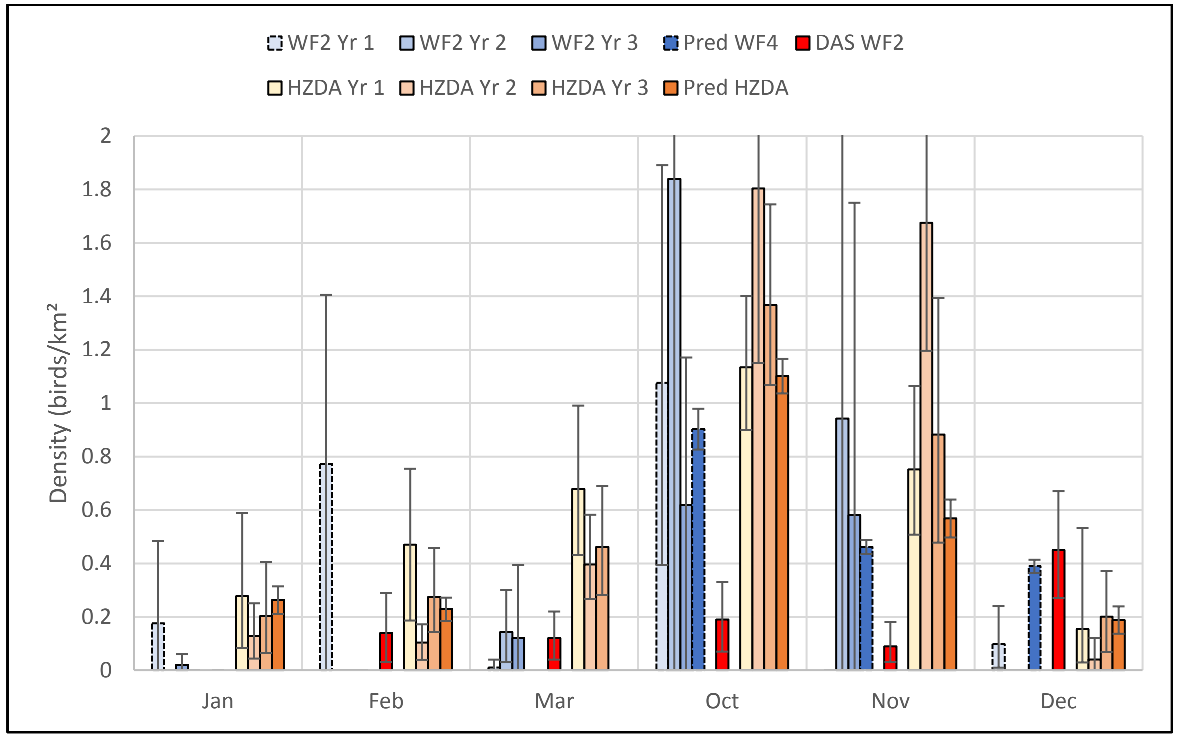

Figure A.3: Comparison of predicted density of Atlantic puffin in Hornsea Three project area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.

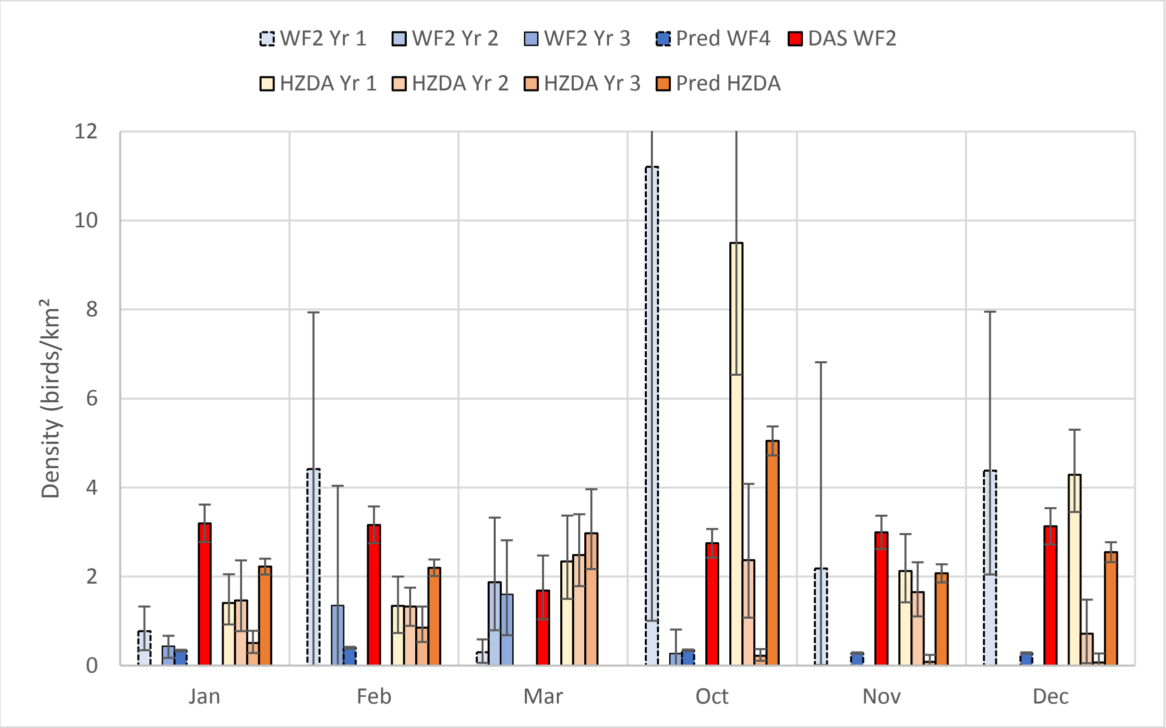

Figure A.4: Comparison of predicted density of razorbill in Hornsea Three project area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.

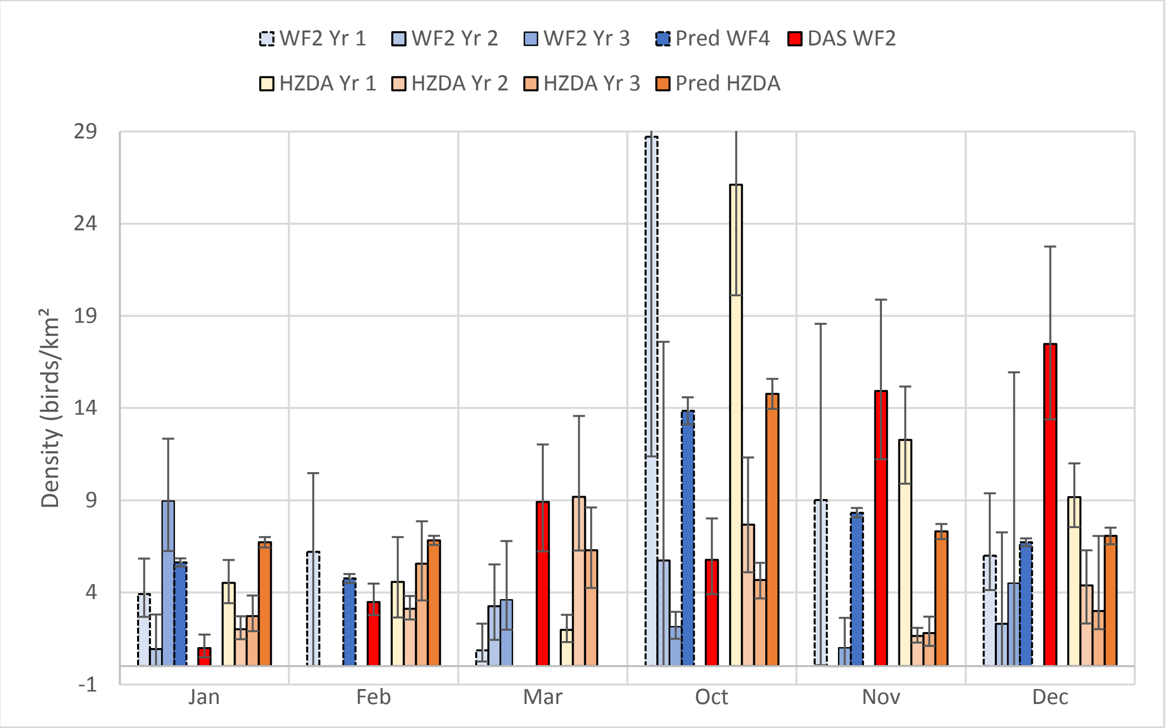

Figure A.5: Comparison of predicted density of common guillemot in Hornsea Three project area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.

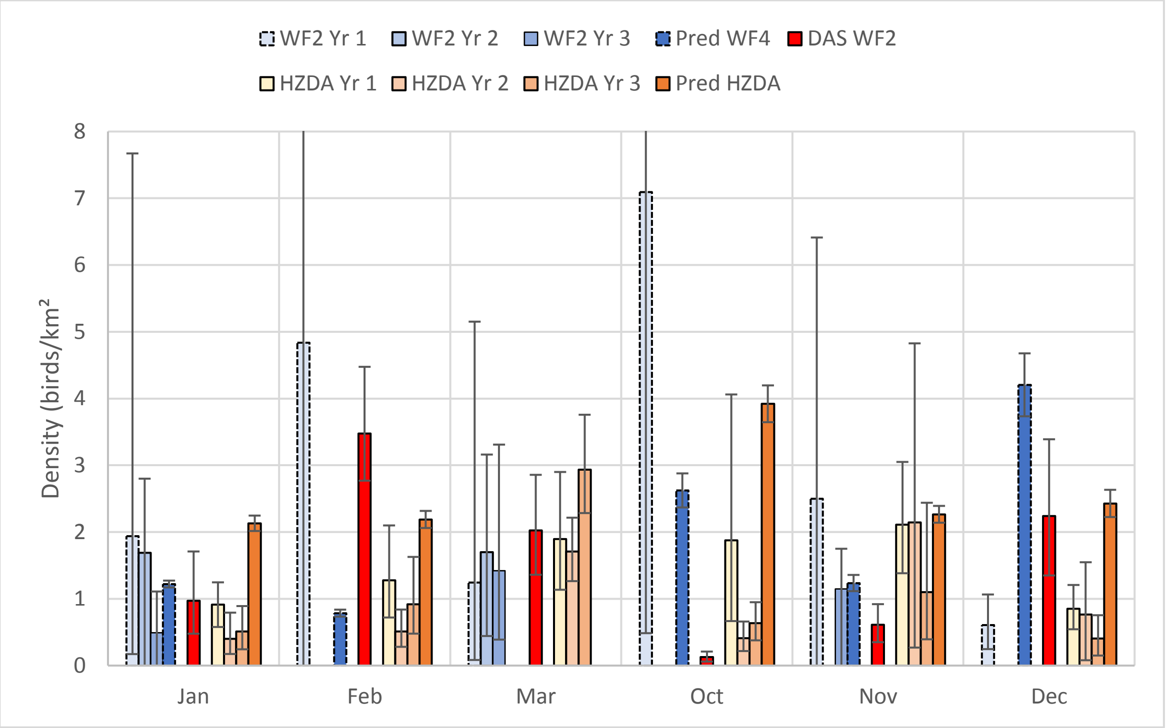

Figure A.6: Comparison of predicted density of black-legged kittiwake in Hornsea Three project area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.

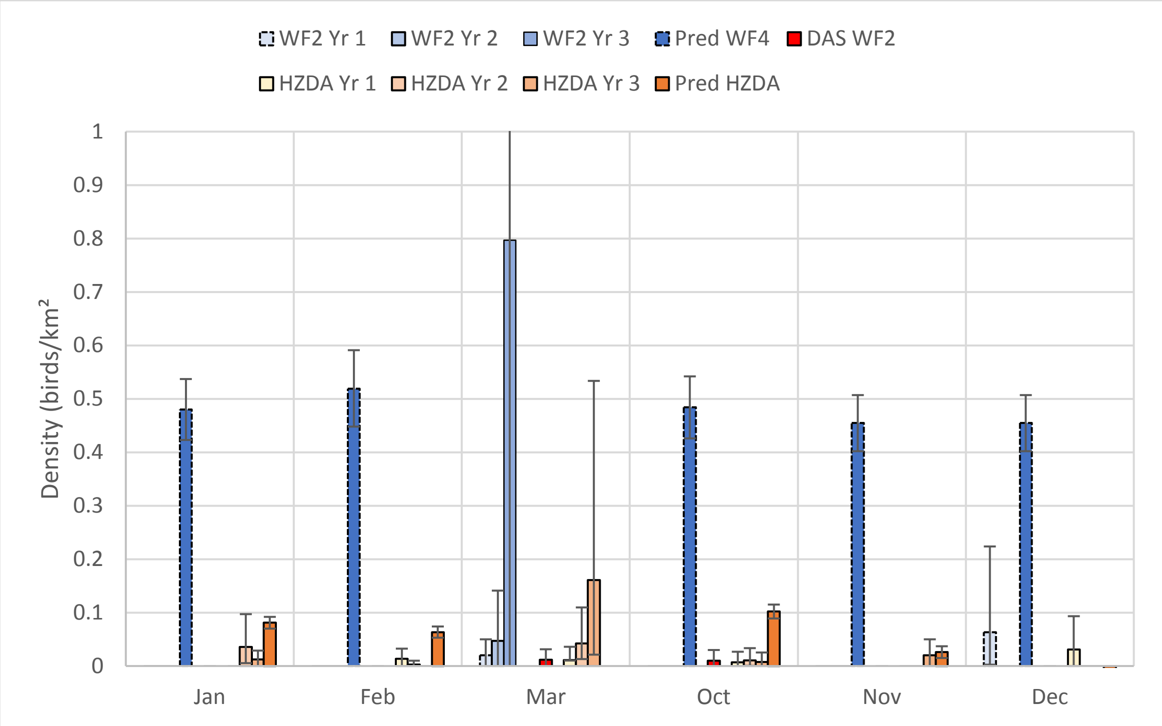

Figure A.7: Comparison of predicted density of lesser black-backed gull in Hornsea Three project area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.

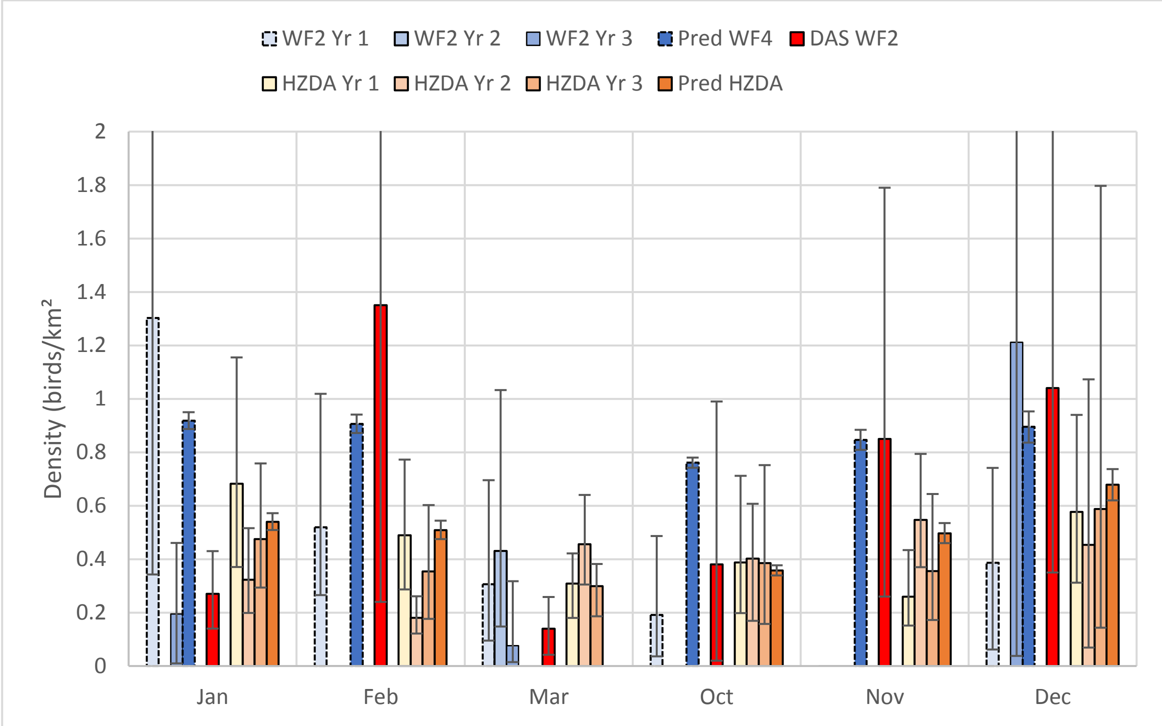

Figure A.8: Comparison of predicted density of great black-backed gull in Hornsea Three project area and the Hornsea ZDA from empirical boat-based and digital aerial survey data and from modelled predictions.