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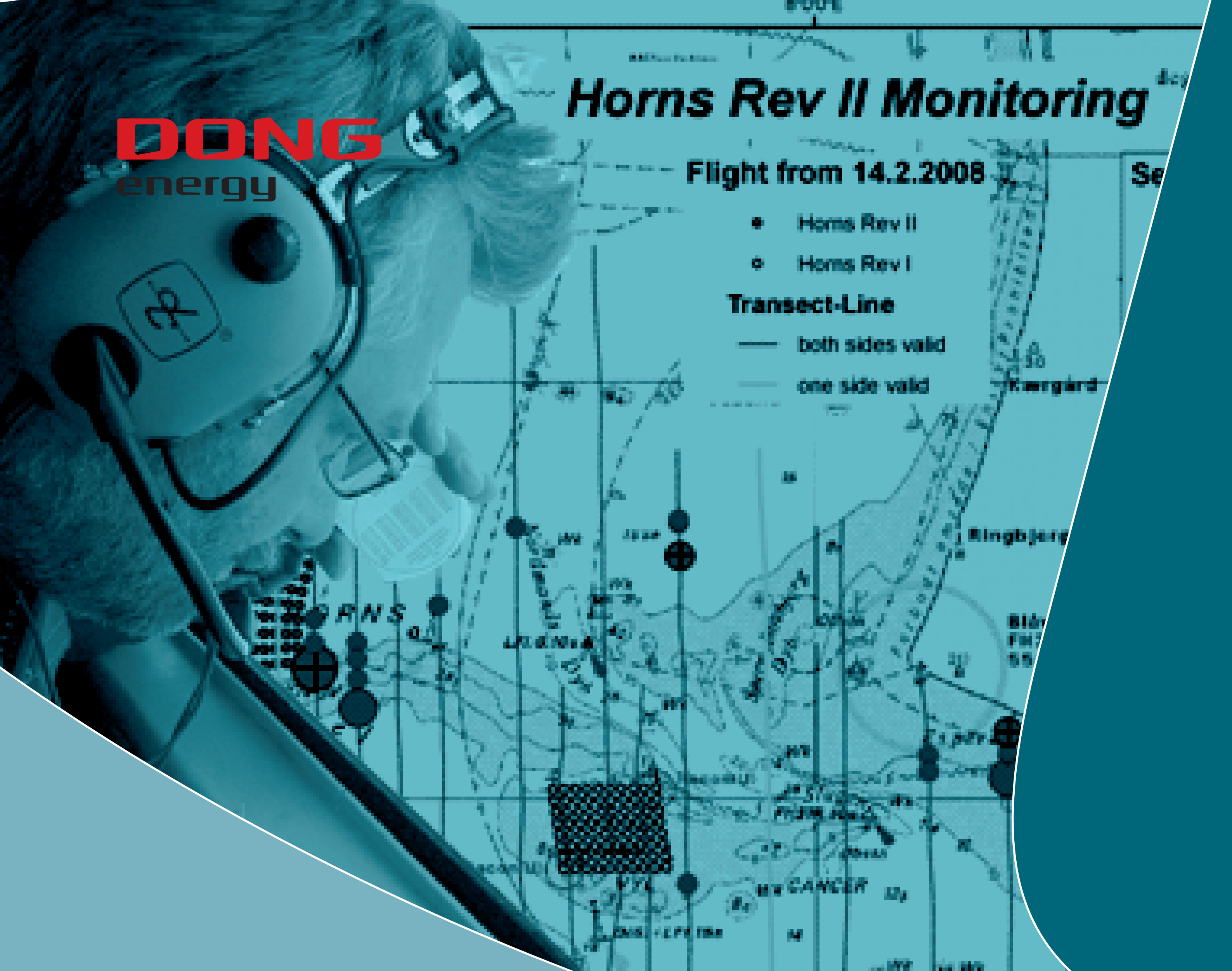

Horns Rev II Offshore Wind Farm Monitoring of Resting Waterbirds

Baseline Studies 2007-08

DHI WATER • ENVIRONMENT • HEALTH

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1 SUMMARY

DONG Energy has commissioned a consortium of Orbicon and DHI in association with BIOLA to undertake aerial surveys of Common scoter *Melanitta nigra* and other resting waterbirds as part of the monitoring program for the planned Horns Rev 2 offshore wind farm. This report contains the results of the baseline phase running from October 2007 to April 2008. With respect to resting birds the monitoring program is focused on documenting the use of the planned site by Common scoter. The statistical design of the monitoring program is based on the BACI approach with inclusion of a dynamic habitat model

The establishment of the Horns Rev 2 offshore wind farm (HR2 OWF) was granted by the Department of Energy on the 19th March 2007 on the basis of DONG Energy's application of 13th October 2006. The location of the HR2 OWF is planned for the outer part of Horns Rev, and it consists of a total of 91 turbines, each 2.3 MW which are placed with 13 east-west oriented rows of 7 turbines. The monitoring on resting birds was based on the aerial line transect methodology. Spatial prediction models were developed for Common scoter and Red-throated/Black-throated divers (*Gavia stella/arctica*) using hydrographical, physical and bathymetric data and modelled distributions of the two key prey species for scoters in this area; American razor clam *Ensis americanus* and the cut trough shell *Spisula subtruncata*. The abundance of scoters and divers was estimated for each survey.

Intensive commercial fishing activities were mainly recorded in two zones; the waters deeper than 10 m southeast and northwest of Horns Rev, respectively. These fishing activities affected bird distributions, especially the distribution of Larus-gulls and kittiwakes *Rissa tridactyla*. The abundance of most species of waterbirds in the area of the planned HR2 OWF was relatively dynamic with large variations in numbers recorded between surveys. Two species groups, however, seemed to use the area more frequently: Red-throated/Black-throated diver and Common scoter. The distribution of Common scoter has changed markedly in the eastern North Sea since 2004. Smaller or larger proportions of birds normally located in the area close to Blåvands Huk from time to time, occurring offshore along the central and western parts of Horns Rev. These general patterns were also recorded during these surveys with medium concentrations of less than 3000 birds, or 10% of the total observed in the area, at the shallow ground VovVov located at the southern periphery of the planned wind farm site. The most significant monitoring result was the findings of the concentration of Red-throated/Black/throated divers at lines crossing or close to the planned wind farm. This result is in line with the survey results from the monitoring programme of Horns Rev 1 and with existing models of diver distribution in the German Bight depicting long-shore aggregations in the same areas coinciding with the long-term mean position of the estuarine front.

Spatial models of the average distribution of Common scoter and divers during the six baseline surveys were developed. The GLM model for scoters indicated that the birds were significantly correlated with the estimated habitat suitability for *Spisula subtruncata*, with areas close to the coast and areas at longer distances from HR1 OWF. The model indicated high densities (> 100 birds/km^2) in the eastern-most part of the modelled area between Cancer and Blåvands Huk, with densities peaking around the 10 m

curve off the Danish west coast. The model predicted low-medium densities throughout the rest of the model area, with average densities of scoters in the HR2 OWF ranging between 10 and 40 birds/km^2, while densities in the HR1 OWF ranged between 0 and 25 birds/km^2. The GLM model for divers indicated that the birds were significantly correlated with the gradient zone between the estuarine water mass and the water mass of mixed North Sea and estuarine water masses from the southern German Bight. The deployment of the model showed enhanced average densities throughout the estuarine gradient zone extending 10-15 km E-W, and areas of higher densities over the western sector of Horns Rev, in the HR2 OWF site and over the plains to the north of here.

The survey data collected in combination with dynamic model data on potential food supply and hydrographic conditions are judged as sufficient for the baseline for the HR2 OWF monitoring programme. As the model data cover the entire period from 2000 to present BACI tests may be designed to include some or all of the data collected during the PSO monitoring programme in the baseline.

2 DANSK RESUME

Et konsortium bestående af Orbicon og DHI i samarbejde med BIOLA har på vegne af DONG Energy gennemført flytællinger af sortænder *Melanitta nigra* og andre vandfugle som en del af overvågningsprogrammet for den planlagte Horns Rev 2 havvindmøllepark. Denne rapport indeholder resultaterne af baseline, som blev gennemført mellem oktober 2007 og april 2008. Med hensyn til rastende fugle er overvågningsprogrammet fokuseret på at dokumentere forekomsten af Sortand i det planlagte vindmølleområde. Det statistiske design for overvågningsprogrammet er et BACI-design med anvendelse af en dynamisk habitatmodel.

Tilladelsen til at bygge Horns Rev 2 havvindmølleparken blev givet af Energistyrelsen den 19. marts 2007 på basis af DONG Energy's ansøgning af 13. oktober 2006. Placeringen af vindmølleparken er planlagt til at være på den ydre del af Horns Rev, og mølleparken består af 91 møller på hver 2.3 MW, som er placeret i 13 øst-vestgående rækker med hver 7 møller. Overvågningen af de rastende fugle blev gennemført som flybaserede linietransekttællinger. Rumlige statistiske modeller blev beregnet for Sortand, Rødstrubet og Sortstrubet Lom ved brug af hydrografiske, fysiske og bathymetriske data og modellerede udbredelser af de to vigtigste byttedyr for sortænder i området; Amerikansk knivmusling *Ensis americanus* og Hvælvet trugmusling *Spisula subtruncata*. Bestandsstørrelsen af Sortand og Rødstrubet og Sortstrubet Lom blev estimeret for hver tælling.

Intensive kommercielle fiskeriaktiviteter blev især observeret i to zoner; områderne på mere end 10 m dybde sydøst og nordvest for Horns Rev. Disse fiskeriaktiviteter påvirkede udbredelsen af fugle, især måger og ride *Rissa tridactyla*. Forekomsten af vandfugle i det planlagte mølleområde var karakteriseret ved stor variation i antallet af observerede fugle imellem tællingerne. To arter (grupper) forekom imidlertid mere regelmæssigt i området i relativt store antal: Rødstrubet og Sortstrubet Lom og Sortand. Udbredelsen af Sortand har ændret sig markant i den østlige del af Nordsøen siden 2004. Mindre eller større andele af de fugle, der normalt forekommer i et området tæt på Blåvands Huk, er fra tid til anden udbredt offshore langs den centrale og vestlige del af Horns Rev. Disse generelle mønstre blev også registreret under disse tællinger med en koncentration på omkring 3000 fugle, eller 10 % af totalen i området, på grunden Vov-Vov beliggende i den sydlige periferi af mølleparken. Det mest signifikante resultat af overvågningen var tilstedeværelsen og koncentrationen af Rødstrubet og Sortstrubet Lom langs linjer der gennemskærer eller er tæt beliggende på den kommende havmøllepark. Resultaterne er på linie med survey-resultaterne fra overvågningsprogrammet i forbindelse med Horns Rev 1 og med eksisterende modeller for udbredelsen af lommer i Tyske Bugt, der peger på koncentrationer i områder overlappende med langtids-middelpositionen for den estuarine front.

Rumlige modeller blev udarbejdet på den gennemsnitlige udbredelse af Sortand og lommer gennem de seks surveys. GLM-modellen for Sortand indikerede at fuglene var signifikant korrelerede med habitatkvaliteten for *Spisula subtruncata*, med områder tæt på kysten og med områder udenfor HR1 mølleparken. Modellen indikerede høje tætheder (> 100 fugle/km^2) i den østlige del af området mellem Cancer and Blåvands Huk, med maksimumtætheder omkring 10 m kurven udfor Vestkysten. Modellen estimerede lave-medium tætheder i resten af modelområdet, med middeltætheder af sortænder i HR2 mølleparken på mellem 10 and 40 fugle/km^2, og med tætheder i HR1 mølleparken på mellem 0 og 25 fugle/km^2. GLM-modellen for lommer indikerede at fuglene var signifikant korrelerede med gradientzonen mellem estuarine og mixede Nordsøvandmasser. Applikationen af modellen viste forhøjede tætheder over hele gradientzonen over en strækning på 10-15 km øst-vest, og områder med højere tætheder over den vestlige sektor af Horns Rev, i HR2 mølleparken og over sandfladerne nord herfor.

De indsamlede surveydata i kombination med de dynamiske model data på den potentielle mængde af føde og hydrografiske forhold vurderes som tilstrækkelig for en baseline for HR2 overvågningsprogrammet. Eftersom model data dækker hele perioden fra 2000 til i dag kan BACI tests udføres med dele af eller alle data indsamlet under PSO overvågningsprogrammet.

3 INTRODUCTION

3.1 Background

DONG Energy has commissioned a consortium of Orbicon and DHI in association with BIOLA to undertake aerial surveys of Common scoter *Melanitta nigra* and other resting waterbirds as part of the monitoring program for the planned Horns Rev 2 offshore wind farm. The establishment of the Horns Rev 2 offshore wind farm (HR2 OWF) was granted by the Department of Energy on the 19th March 2007 on the basis of DONG Energy's application of 13th October 2006.

This report contains the results of the baseline monitoring on resting waterbirds undertaken November 2007 – April 2008.

3.2 The Horns Rev II Project

3.2.1 Location

The location of the HR2 OWF is planned for the outer part of Horns Rev, a sand bank which stretches from the coast of Denmark (Blåvands Huk) and 40 km westwards, Figure 3-1. The distance from the HR2 OWF to Blåvands Huk is 30 km. The minimum distance between the existing OWF on Horns Rev and the planned HR2 OWF is 14 km. The water depth at the site of the HR2 OWF varies between 6 and 18 m. The HR2 OWF has been designed as an arc north of the shallow ground VovVov on the western Horn Rev.

The HR2 OWF consists of a total of 91 turbines, each 2.3 MW which are placed with 13 east-west oriented rows of 7 turbines. Due to the design of the OWF the distance between the rows will vary from 700 m in the eastern part to 900 m in the western part, Figure 3-2. The distance between individual turbines is 550 m.

Figure 3-1 and Figure 3-2 also show the proposed placement of three 15 MW test mills. The transformer station will be located 1 km east of the wind farm. 16-20 m northeast of the transformer station an accommodation platform will be installed with a gangway connecting the two platforms.

The turbines will be connected by east-west running 34 kV cables, which will be collated into a single cable in the eastern part of the OWF, which then is connected to the transformer station, Figure 3-2.

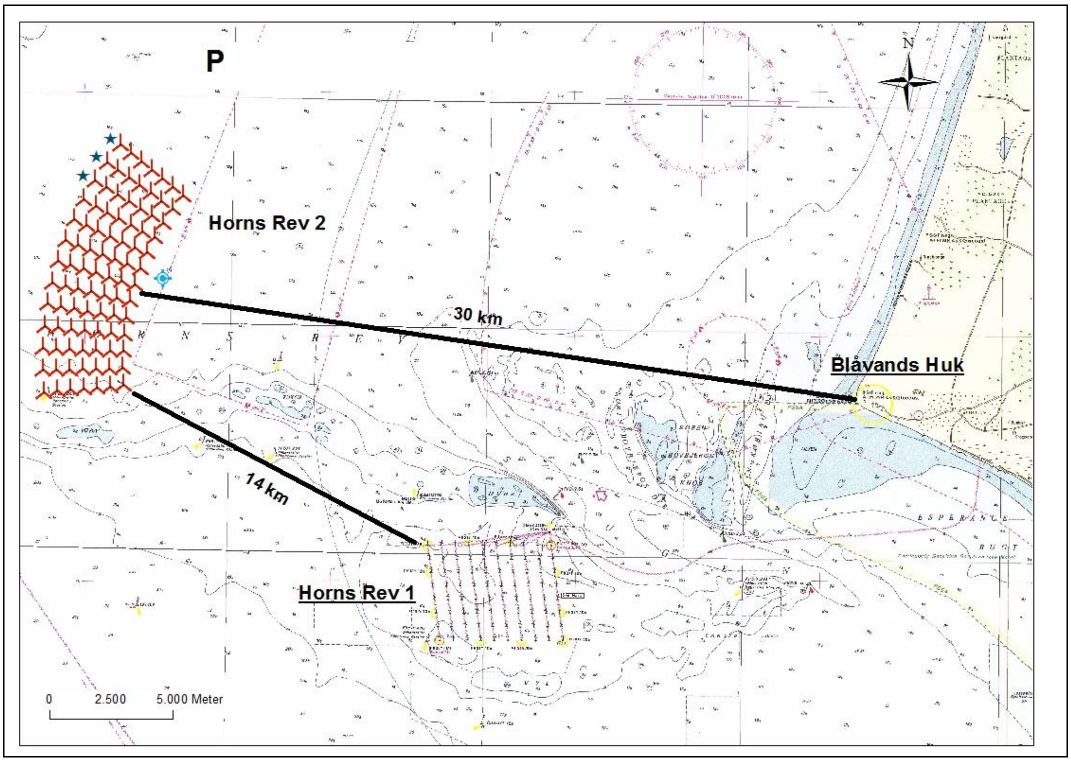

Figure 3-1. The location of the HR2 OWF relative to Blåvands Huk and the Horns Rev 1 OWF

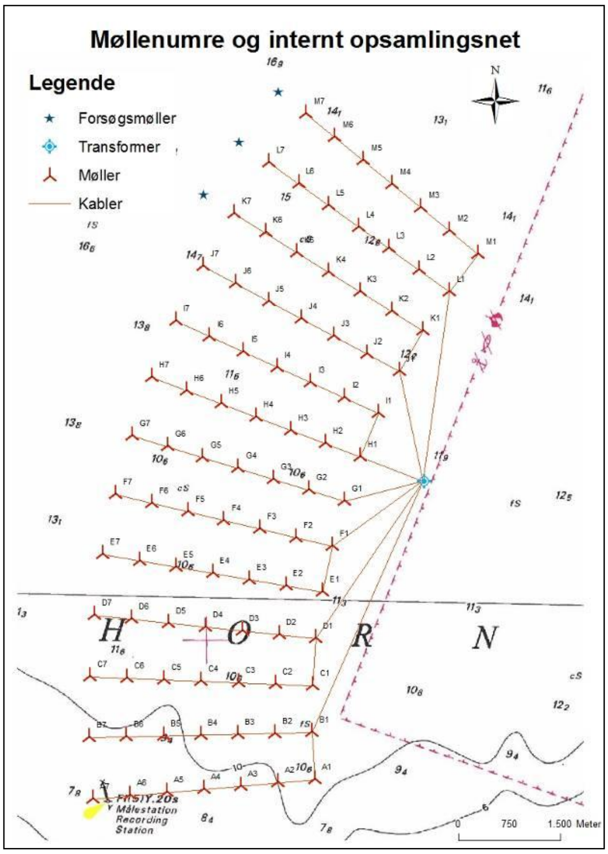

Figure 3-2. Turbine numbers and planned cables for the HR2 OWF.

3.2.2 Free zone

A free zone of 4 km towards the south and west and 2 km towards the north and east has been granted to DONG Energy for this OWF.

3.3 Monitoring requirements and targets in relation to resting birds

The requirements for the monitoring programme for Horns Rev 2 state that the methodologies should as far as possible be based on the same field methods as used in relation to the PSO monitoring programme for the Horns Rev 1 wind farm and in the investigations carried out as part of the EIA for Horns Rev 2. Thus, the monitoring on resting birds has been based on the aerial line transect methodology. With respect to resting birds the monitoring program is focused on documenting the use of the planned site by Common scoter. The statistical design of the monitoring program will be based on the BACI approach with inclusion of dynamic habitat co-variables from a habitat model, which will be running parallel to the surveys. The parameters of the habitat model will also feed into the description of the distribution of food basis for Common scoter (Skov et al. 2008).

4 METHODS

4.1 Study period

The study period for the investigation has been chosen from October to April to cover most of the time, when important numbers of Common scoters are foraging in the area of Horns Rev. Because of the late start of the project in November and a long period of bad weather conditions in November and December the first aerial survey was not carried out before mid of December 2007.

4.2 Study area and selected species

The strategy of the survey was to provide coverage of a relatively large sector around the planned HR2 OWF and the entire width of Horns Rev, including the coastal area adjacent to Horns Rev and the wind farm area of Horns Rev 1, without expanding the framework for each survey beyond what can easily be surveyed during one day in winter.

4.3 Aerial surveys of birds

The survey methodology closely followed the modified line transect survey technique with four perpendicular distance bands applied during the Horns Rev 1 monitoring programme (Noer et al. 2000, Diederichs et al. 2002, Petersen & Fox 2007). The surveys have been performed from a high-winged, twin-engine Partenavia P-68 (Figure 4-1; Figure 4-4), equipped with “bubble windows”, at an altitude of 250 feet (76 m) and with a cruising speed of 100 knots (185 km/h). Each survey was carried out by two experienced observers, which were placed at the left and right bubble window at the middle seats (list of observers Table 4-1). Data were collected only during good or moderate survey conditions (sea state < 3 bft, visibility > 5 km, moderate glare). Further details of the aerial survey techniques are given in Christensen et al. (2006) and Diederichs et al. (2002).

All observations have been recorded by using a dictaphone. Sightings were recorded to the nearest second (in UTC, watches were synchronised with an on-board GPS before every flight) and positions have been logged by a GPS every 3 sec. Positions and observation data have been stored in SQL/Access databases linked to ArcGIS.

Determination of species, behaviour, age, sex and registration of numbers are much more difficult to carry out from an aircraft than from a ship because the animals can be seen for a short period of time only and because it is not possible to work with binoculars. Groups of more than 50 individuals can only be estimated.

Beside birds all marine mammals have been recorded and if possible a swimming direction and the behaviour has been noted. Additional notes were made for ships and fishing vessels.

Because of the weather conditions and availability of survey planes it was not possible to carry out a survey each month, and accordingly some surveys had to be postponed to the following month (Table 4-1).

Table 4-1. Overview over the conducted flights for the project Horns Rev II.

light number	Flight month, planned	Date of flight	Weather conditions	Observer
1	November 2007	13.12.2007	Mostly sea state 1 (in smaller parts 2), little glare and reflections; good conditions	Werner Piper, Martin Laczny
2	December 2007	14.02.2008	Offshore sea state mostly 2, towards land 1, some glare, little reflections; moderate to good conditions	Werner Piper, Martin Laczny
3	January 2008	16.03.2008	Sea state mostly 2 (minute parts 3 and 1), some glare and reflections; moderate conditions	Werner Piper, Henrik Skov
4	February 2008	26.03.2008	Sea state 2-3, strong glare in western parts (one sided towards the south); predominantly moderate conditions	Martin Laczny, Manuela von der Heyde
5	March 2008	14.04.2008	Sea state mostly 2, some glare and reflections; moderate conditions	Martin Laczny, Gudrun Hofmann
6	April 2008	23.04.2008	Sea state mostly 2, some glare and little reflections; moderate conditions	Martin Laczny, Thilo Christophersen

Although we cooperated with four different airlines, the availability of planes was not granted. Several times planes were in maintenance and in one period all of the planes were broken or in maintenance. Also in some of the longer periods of adverse weather conditions planes were not available as well, which is not documented here. No plane was available on the following dates:

08.02.2008	Until	13.02.2008
15.02.2008	Until	18.02.2008
08.03.2008		
15.03.2008		
07.04.2008	Until	08.04.2008
10.04.2008		
15.04.2008		

Details on the aerial surveys carried out can be found in Table 4-2. Because of military activity not all transects could be performed to there fully length on each flight. Also parts of the flown transect lines (including observations) had to be set as **not valid** because of the weather condition (e.g. sea state partly over 3 and strong glare).

Table 4-2. Performed aerial surveys in the Horns Rev area from Dec. 2007 to Apr. 2008 showing the survey dates and the effort, which has been carried out for the counts on each side and the total length from both sides of the aircraft

Date	**Flight length (km)**	**Valid length left side (km)**	**Valid length right side (km)**	**Total length for both sides (km)**	**Comments**
13-Dec-07	645.91	645.91	645.91	1291.82	
14-Feb-08	645.42	645.42	523.57	1168.99	Partly strong glare on one side
16-Mar-08	645.10	526.68	645.10	1171.78	Partly strong glare on one side
26-Mar-08	625.64	625.64	546.65	1172.29	Transects 18 to 21 had to be cut in the north for military activity at Skallingen, partly strong glare on one side
14-Apr-08	646.00	544.74	646.00	1190.74	Partly strong glare on one side
23-Apr-08	597.02	597.02	480.47	1077.49	The eastern transects had to be cut in the north for military activity at Skallingen, partly strong glare on one side

It is difficult to measure distances from a plane carrying out a survey over sea. One method to determine the band widths, which was applied in this study, is the use of clinometers (Suunto PM 5 / 360 PC). With a flight altitude of 76 m (250 Fuß) the following band widths (Table 4-3 and Figure 4-2) have been chosen (after Diederichs et al. 2002).

Table 4-3. Overview over the band widths, which were used in this study (after Diederichs et al. 2002).

Band D:	from	0 m (90°)	Until	45 m (60°)
Band A:	from	45 m (60°)	Until	167 m (26°)
Band B:	from	168 m (25°)	Until	442 m (11°)
Band C:	from	443 m (10°)	until the middle of two transect lines	

Figure 4-1. Survey plane Partenavia P68 Observer.

The distance between transect lines in the HR2 OWF and associated impact area (4 km distance from outermost turbines) has been 2 km, while the distance between survey lines in the remainder of the area has been 4 km. To gather more data about the birds in the Horns Rev I wind farm we also narrowed the transect lines to 2 km distance there (Figure 4-3). We were able to fly three short lines through the Horns Rev 1 wind farm as long as the wind was not too strong (Figure 4-3).

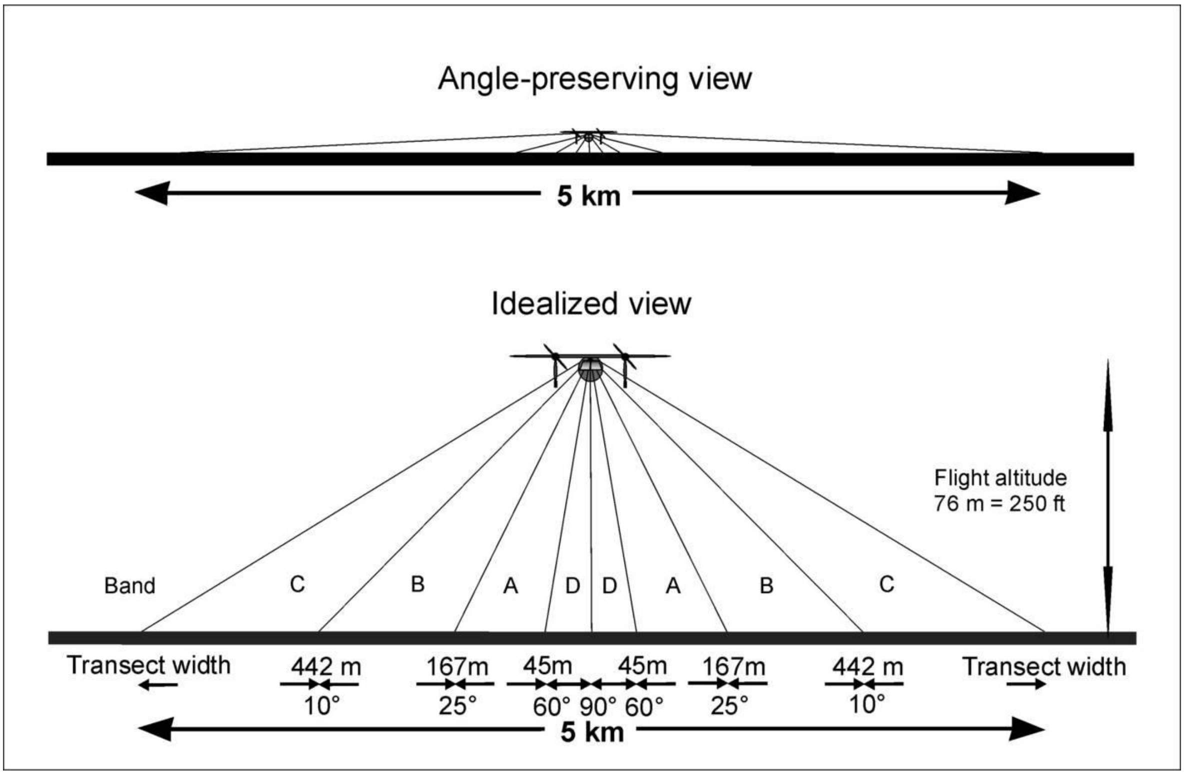

Figure 4-2. Method of aerial surveys and applied band widths.

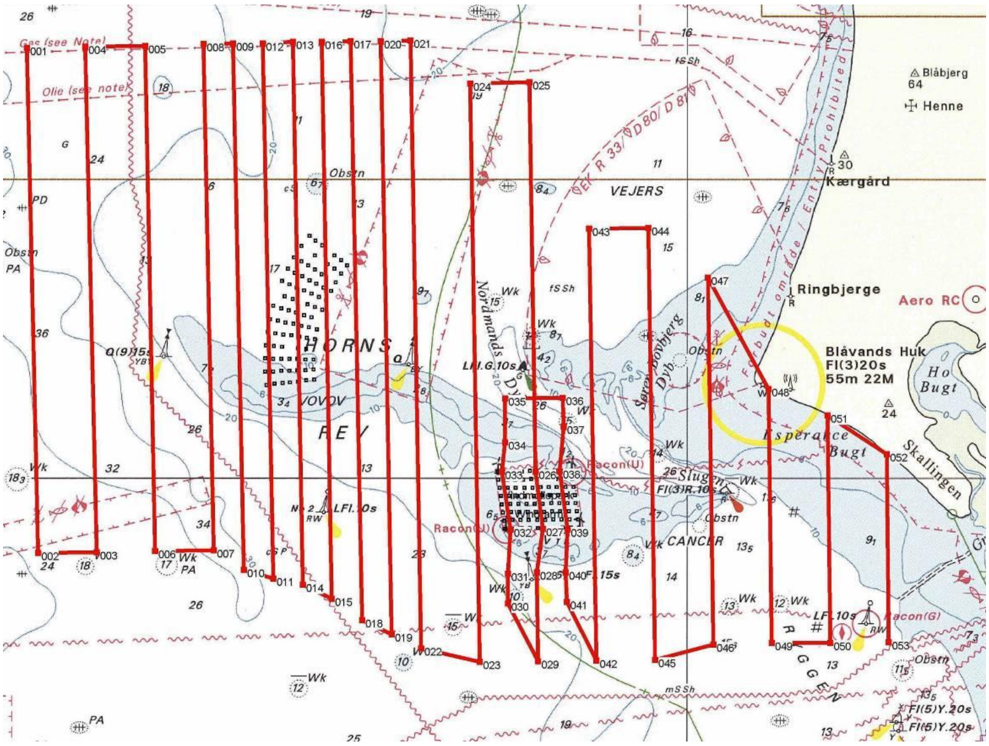

Figure 4-3. Transect design.

Figure 4-4. The Partenavia passing the Horns Rev I wind farm.

4.3.1 Human activities during aerial surveys

In general only few recreational activities are observed in the Horns Rev area. During calm weather conditions in the summer occurrence of a few sport fishermen is possible, and maybe a few sport hunters is observed during autumn and winter (Petersen et al. 2006). The level of commercial fishing activities on Horns Rev is not known in detail, however the fishing activities recorded during the surveys have been recorded, and the results indicate intensive fishing activities in waters deeper than 10 m southeast and northwest of Horns Rev, Figure 4-5 and Figure 4-6.

Figure 4-5. Fishing vessel in the Horns Rev area.

The main traffic route taken by the ferries and commercial ships heading to or leaving from Esbjerg is located several kilometres south of the Horns Rev 1 wind farm. Some traffic, mainly coasters and trawlers, passes through the channel of Slugen east of the wind farm area (Petersen et al. 2006).

The frequency of maintenance work associated with the wind turbines of Horns Rev 1 is highly dependent on the weather conditions. During good weather conditions either boats or helicopters may be taking technicians to the windmills several times per day, Figure 4-7.

Birds like the Red-throated and Black-throated divers (*Gavia stella/arctica*) and the Common scoter are known to react strongly on approaching boats and aircrafts and can be easily displaced by approaching ships. Other birds like gulls show a fully different behaviour and may be attracted by ships. To get an idea about the frequency of human activity during the aerial survey, data on boats and fishery activities were collected in the same way as the bird data.

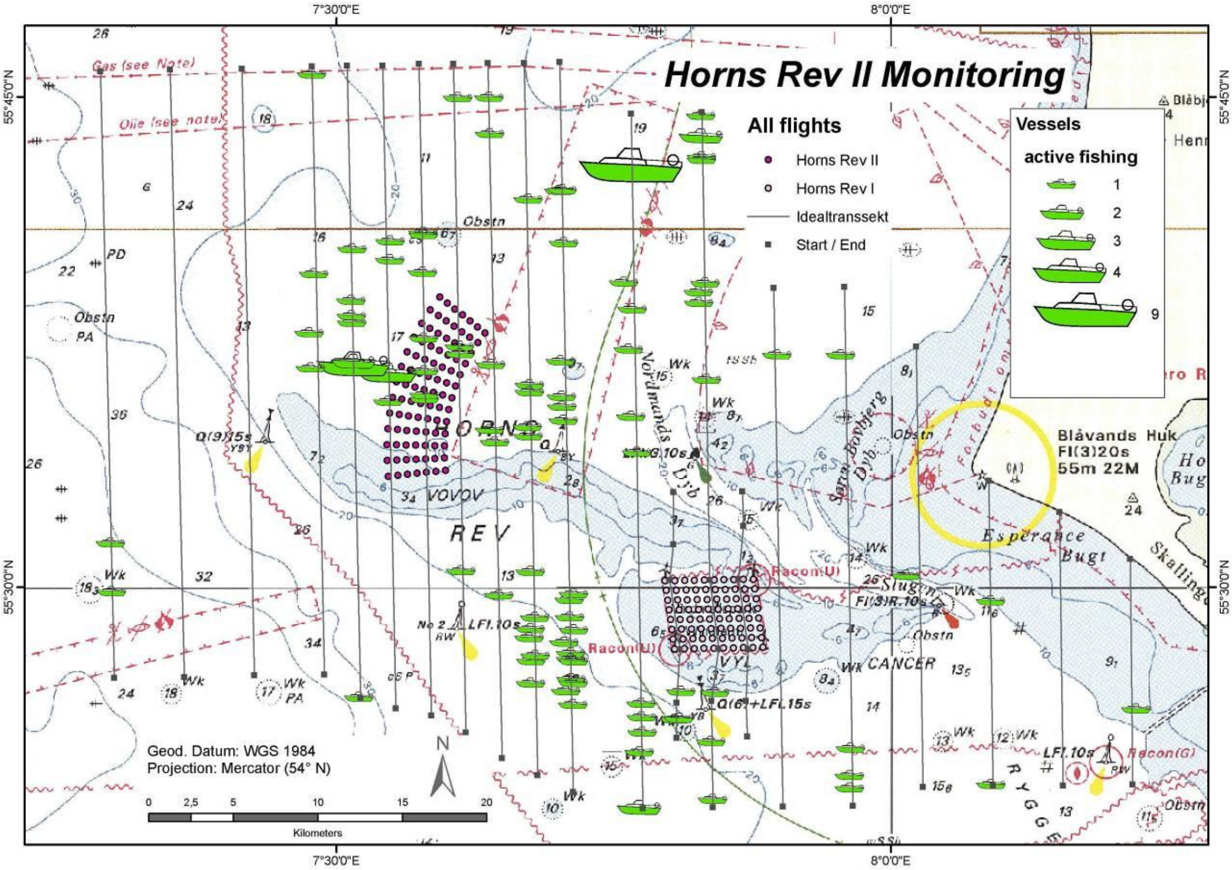

Figure 4-6. Observations of commercial fishing activities during the six aerial surveys. .

Figure 4-7. Maintenance boat in the Horns Rev I wind farm.

4.4 Data analyses

4.4.1 Post-processing and mapping of aerial survey data

All observations and GPS positions were stored in a special SQL geo-database (FULMAR) for aerial and ship-based surveys, which is linked to ArcGIS, and which exports the results to a Microsoft Access® database. The post-processing chain starts by transcribing the general flight survey data (e.g. date, observer, flight altitude etc.) from the dictaphones into the database. The next step is the import of the GPS-track into the database by using a special extension for ArcGIS, which is started by the database. In ArcGIS the whole flight track is shown. The start and end points of each transect lines are marked and then the track points with their position and time are imported into the database. The user of the database can now view track points, time and the columns for the sightings. Every observation (precision one second) will be sorted by time to the nearest track point (precision 3 seconds). Also the weather conditions are stored into the database during this step. Red-throated and Black-throated divers are generally very difficult to separate using aerial observations, and data of both species have been lumped for analysis. Also Razorbill and Guillemot are very difficult to separate and accordingly both species have been lumped

Routines have been programmed to minimize mistyping and input of erroneous data. After finishing the data input different tools are used to visualize the observed birds/marine mammals along the transect lines. The next step is the validation of the data by a senior biologist, who will also check the weather conditions along all the transect lines on each side of the aircraft according to sea state, glare and visibility. If the observations of parts of the lines affected by strong glare, sea state over Bft 3 or poor visibility, he will mark that period as "invalid". After the evaluation, and if necessary by additional confirmation of the observer, the data will be exported to a report-file, which is a Microsoft Access® database file. Here, all common types of results are generated by queries. Two tools are generating the export files for ArcGIS and population estimation in Distance. The last step is to visualize the data in ArcGIS. All maps have been produced in geographic (latitude/longitude) projection using wgs 84 datum and the digitised nautical map 'INT 1004 – Nordsøen Jyllands Vestkyst' from Kort & Matrikelstyrelsen 2004.

4.4.2 Development of spatial prediction models

Spatial prediction models were developed for the two target species (groups) divers and Common scoters using landscape, topographic, hydrographic and prey data available for the entire study area. The parameters used to predict the density of the two species include current speed at surface, salinity gradient at surface, temperature gradient at surface, water depth, relief of sea floor, complexity of sea floor, distance to shipping lane, distance to coastline, distance to Horns Rev 1 wind farm and modelled distribution of American razor clam *Ensis americanus* and the cut trough shell *Spisula subtruncata*. The hydrographic data were taken from the fine-scale hydrodynamic model set up for the development of models of the distribution of prey to Common scoters, which in turn were used as a substitute for data on prey. The resolution of the spatial models is 500 m, and they were developed using multivariate linear modelling techniques (General Linear Modelling, GLM).

The statistical models were developed through an iterative process which was initiated by an analysis of the spatial structure of the transect data as a means for selecting the scale of controlling parameters. Univariate tests of selected parameters were then undertaken to select those to which the bird observations showed a linear response. Several GLM models, including two-way interactions, with gradually fewer and more important parameters were compared before deciding on the final model. The predicted density values were validated against observed densities. Line transect survey data like the Horns Rev aerial monitoring data display a high degree of spatial autocorrelation, which limits the usefulness of multivariate methods like GLM due to the introduction of inflated significance values and hence unreliable explanatory and predictive power. We attempted to reduce the autocorrelation by aggregating data in 500*500 m squares before analysis.

4.4.3 Estimation of bird abundance

The abundance of Common scoter and Red-throated/Black-throated divers was estimated for each survey using line transect theory and functions, adjustment terms and variance estimators in Distance Ver. 5, Release 2 (http://www.ruwpa.st-and.ac.uk). The detection of birds along a line transect declines with perpendicular distance from the line. The decline is typically non-linear with a high detection from the line to a deflection point in the transect from where the detection gradually drops to low values in the more distant parts of the transect. This distance bias can be corrected using key functions, adjustment terms and variance estimators. Even with relatively low sample sizes the application of line transect theory allows for precise estimation of densities.

Precision of density estimates was achieved by integration of the sources of variance for three parameters: encounter rate, detection probability (all surveys combined) and cluster size. Encounter rate is the number of birds seen per sample (line). Detection probability is the probability of observing an object in the defined area. Cluster size is the number of observed birds (single or flocks). We analysed the data based on the three innermost perpendicular distance bands and exact sizes of clusters from lines 1, 2, 3, 4, 6, 8, 10, 12, 14, 16, 17, 18, 19, 20 and 21. Key functions were evaluated with cosines and simple polynomials for adjustment terms: uniform, half-normal and hazard rate, and the best function was chosen on the basis of minimum AIC values. For divers detection probability within 392 m was modelled using a uniform function with simple polynomials, while a hazard rate function with half-normal key was used for Common scoter.

4.4.4 Establishment of BACI design

Three main hypotheses relating to Common scoter have been formulated on the basis of the results of the Horns Rev 1 monitoring programme (Petersen et al. 2006, Petersen & Fox 2006):

1. During construction and early part of operation scoters are expected to use available feeding habitat in the wind farm and associated impact area less than during the baseline (BACI) and the use is expected to be significantly different from habitats in neighbouring areas;
2. During the later part of operation the use of available feeding habitat in the wind farm and associated impact area will not be different from the baseline and the use is not expected to be significantly different from habitats in neighbouring areas;

3. During construction and operation of Horns Rev 2 the use of available habitat in the immediate surroundings to Horns Rev 1 is not expected to be significantly different from habitats in neighbouring areas.

Critical to testing all three hypotheses is the access to detailed knowledge of the oceanographic and ecological condition in impact and reference areas and knowledge of the distribution of suitable feeding habitats on Horns Rev during all surveys, which can be used as co-variables for the BACI tests (interactions with both treatment and block). Obtaining synoptic dynamic habitat variables concurrently with bird data and incorporating these into analysis is likely to help explain some of the temporal variation in numbers observed during aerial surveys (McLean et al. 2006). Consequently doing so will increase the probability of distinguishing wind farm induced changes in bird numbers from background fluctuations. This method is likely to be the most cost-effective means of increasing the power of aerial surveys to detect changes in bird numbers. The modelling of the availability of American razor clams and cut trough shells *Spisula subtruncata* follows these recommendations (Skov et al. 2008).

4.5 Quality control

Before and after every aerial survey we carried out an equipment check following an approved checklist, which has been developed over more than 250 aerial surveys. In the plane we followed strictly our briefing rules with the pilot (setting the flight altitude, speed, transect start point etc.). All observations of birds, marine mammals and ships were recorded on a dictaphone. After the flight we downloaded the GPS-track to a computer and checked it for completeness. As soon as possible after the flight the tapes had been transcribed by one of the observers directly into a special developed database (FULMAR). Unusual data were marked, commented and the observers were asked for clarification or confirmation of the observations. This procedure is very important to get rid of erroneous data already in the first phase. Later on the data sets were run through different routines to detect mistyping and other errors. Finally, a senior researcher evaluated the data.

General quality assurance and management are conducted and documented in accordance with internationally accepted principles for quality and environmental management as described in the DS/EN ISO 9001 standard.

5 RESULTS

5.1 Bird numbers and distributions recorded 2007-2008

5.1.1 Red-throated/black-throated divers

Red-throated and Black-throated divers are generally very difficult to separate using aerial observations, and the lumped data showed a total sample of birds between 45 and 129 recorded along the transects during the surveys.

The estimates of total abundances in the surveyed region during the six surveys are shown in Table 5-1. The abundance estimates for all six survey were of reasonable precision (< 40 % CV) due to the dispersion of the sightings between the transect lines. The average density in the surveyed area varied between 0.31 and 0.81 birds per km^2 and the estimated abundance between 1078 and 2806 birds. The probability of detection of divers within 392 m perpendicular distance for all surveys combined was 33 % and the effective strip width was 131 m (Figure 5-1).

Survey	Sample size	Density	Abundance	CV (%)
13-12-07	30	0.31	1078	31.4
14-02-08	46	0.42	1472	30.2
16-03-08	30	0.34	1197	38.1
26-03-08	35	0.43	1512	19.0
14-04-08	77	0.81	2806	31.6
23-04-08	26	0.32	1113	26.8

Table 5-1. Survey, sample size (number of flocks), density estimates (densities per km^2) and abundance estimates for the whole survey area and related coefficients of variation for divers during the six surveys.

The distribution was centred at lines around 7º30' E longitude with most aggregations found at lines between longitudes 7º15' E and 7º45' E. As a result quite a few birds were observed within or in the vicinity of the planned HR2 OWF, Figure 5-2. There was, however, no association between divers and the shallow areas of Horns Rev, and increasing densities towards the high density zone were found in water depths from 8 to 30 m. A second, smaller, area of elevated densities close the Danish coast was identified during the flight on the 14^{th} March. Only few birds were observed in the eastern part of Horns Rev, and no birds were observed within the existing OWF.

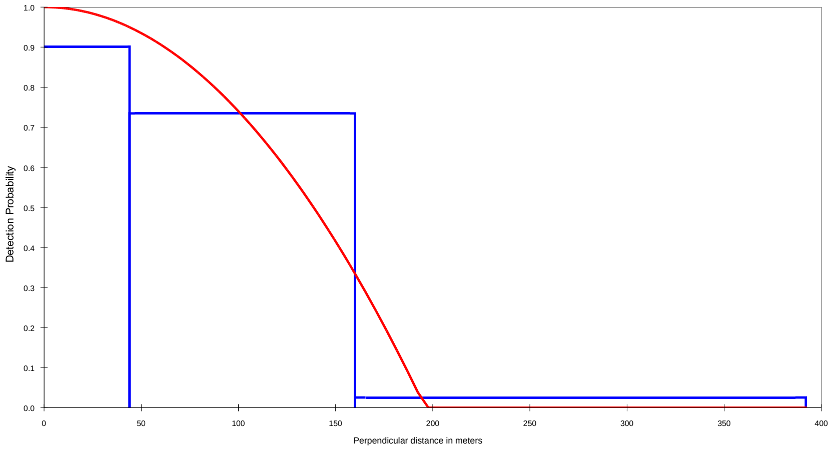

Figure 5-1. Plot of detection probability of divers within 392 m perpendicular distance during the six surveys.

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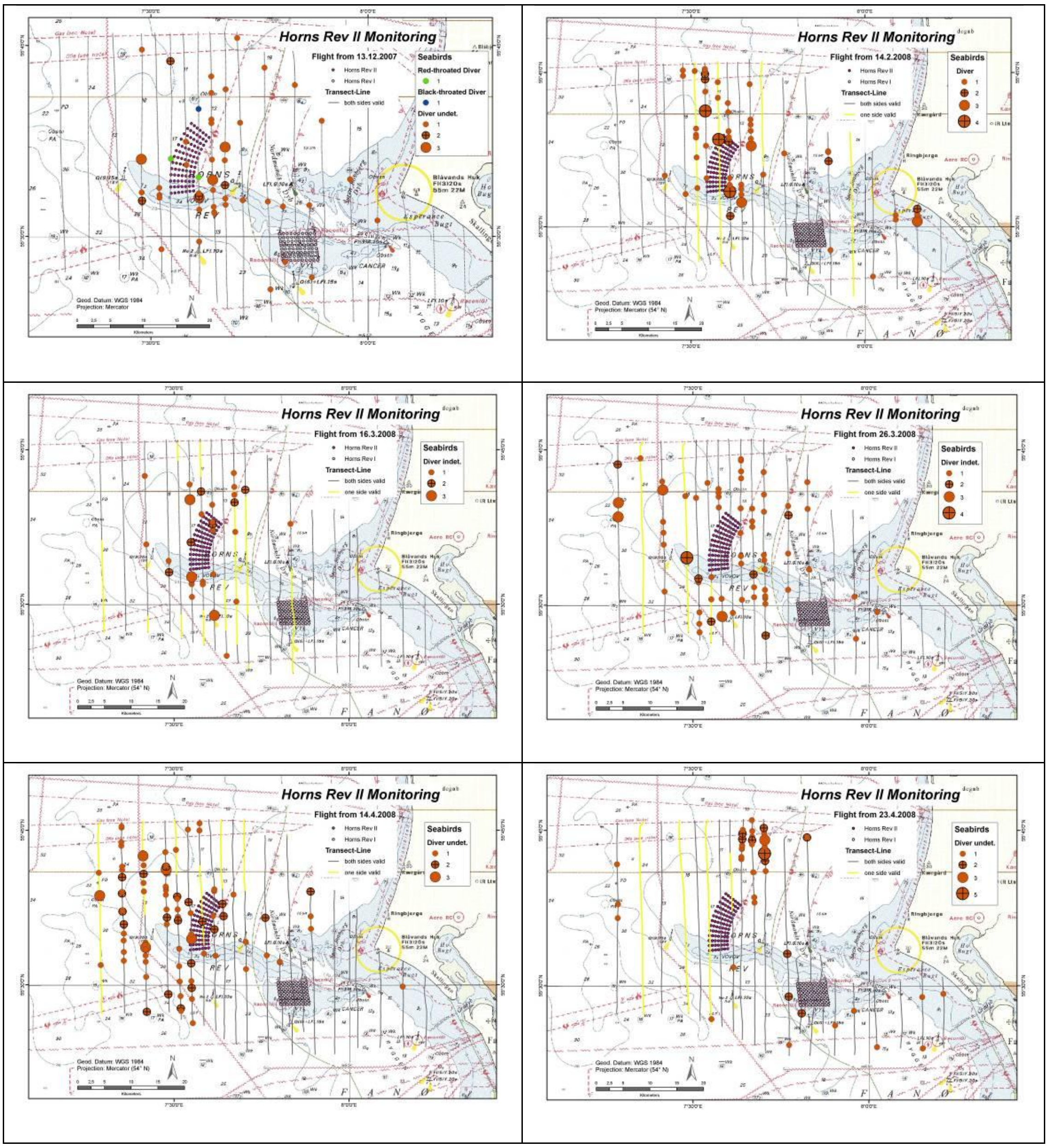

Figure 5-2. Distribution of sightings of Red-throated/Black-throated diver Gavia stellata/arctica *during the six surveys.*

5.1.2 Common scoter

The total sample of birds recorded along the transects during the survey period up to late March when most birds were observed was between 17,000 and 39,500. During this period, the majority of Common scoters were recorded in the far east of the study area; south of Blåvands Huk in Esperance Bugten, just west of Blåvands Huk and on Cancer on the easternmost tip of Horns Rev. A secondary aggregation of scoters holding less than 10% of the birds and with flocks smaller than 1000 was observed in the VovVov area at the southern edge of the planned HR2 OWF. Few birds were seen in the vicinity of the existing OWF, and no birds were seen within the wind farm.

Only the estimates of average density and abundance of scoters for the survey in early April was of sufficient precision to be used as an indication of numbers present in the whole survey area (Table 5-2). The estimated total was almost 70,000 birds. The probability of encounter was 44 % within 392 m, and the effective strip width was 173 m (Figure 5-3).

In early April the total sample of birds was 11,000, and the birds had left the Esperance area and a larger proportion of the birds or approximately 50% were observed over the central and western parts of Horns Rev as well as in the area to the north of the reef (Figure 5-4). A few flocks were seen during this survey within the existing wind farm. During the survey in late April more than 90 % of the birds had left the Horns Rev area; the remaining birds being distributed in more or less the same areas as during the survey in early April.

Survey	Sample size	Density	Abundance	CV (%)
14-04-08	85	19.9	69458	38.5

Table 5-2. Survey, sample size (number of flocks), density estimates (densities per km2) and abundance estimates for the whole survey area and related coefficients of variation for Common scoters during survey on the 14th April.

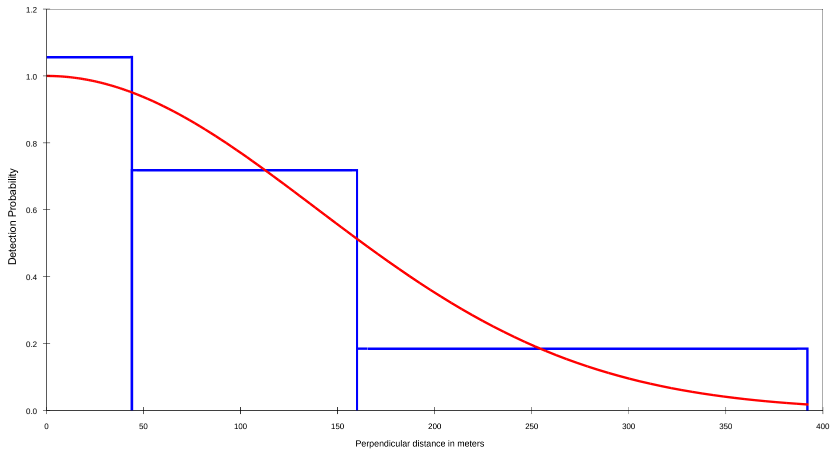

Figure 5-3. Plot of detection probability of Common scoters within 392 m perpendicular distance during the six surveys.

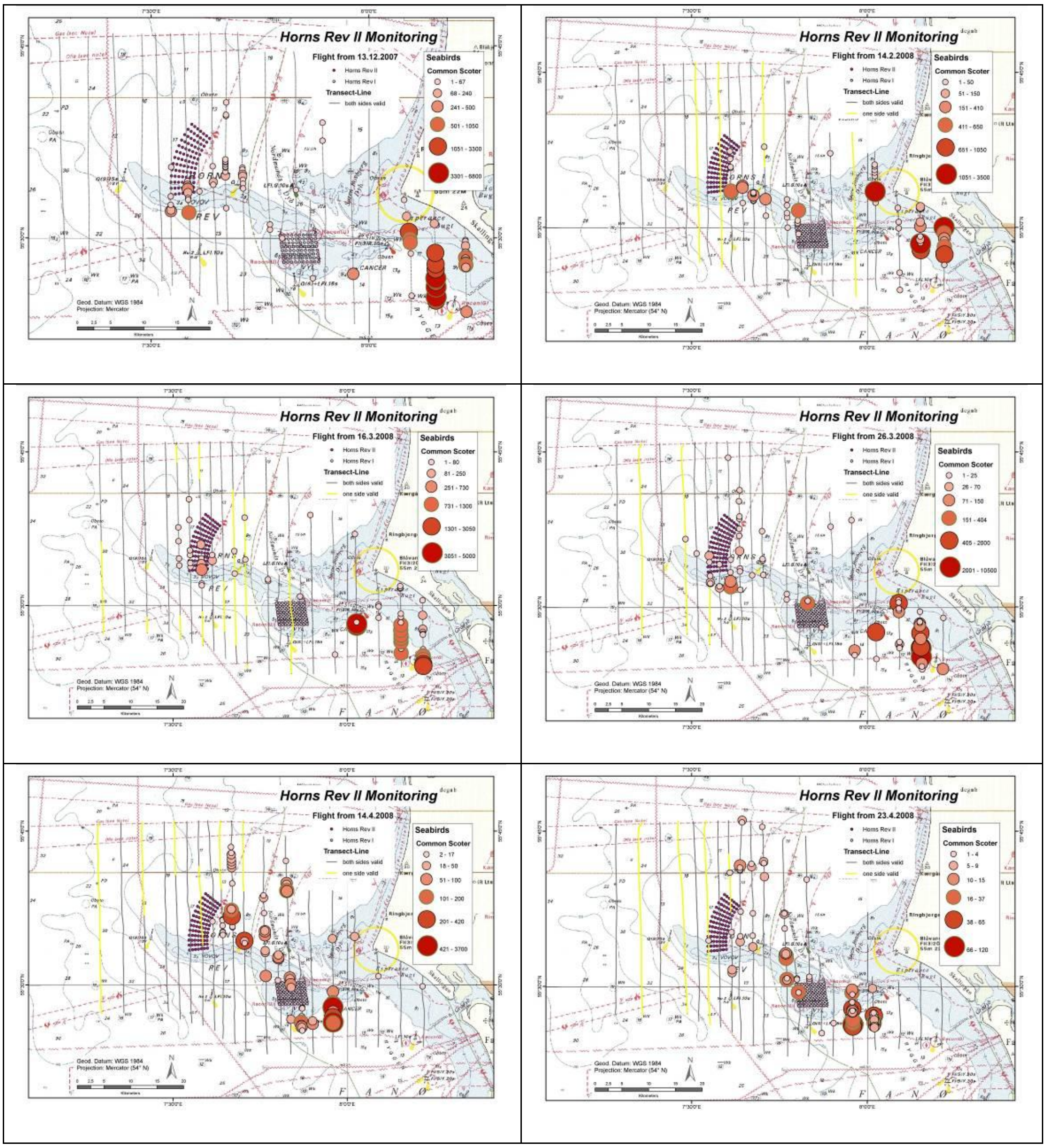

Figure 5-4. Distribution of sightings of Common scoter Melanitta nigra *during the six surveys.*

5.1.3 Larus-Gulls

Both Common gull *Larus canus,* Herring gull *Larus argentatus* and Lesser Black-backed gull *Larus fuscus* were recorded in large numbers during the surveys, the latter species only during the surveys in March and April. The distribution of the gulls differed between species, but in general their distribution was to a large degree determined by the location of fishing activities. Concentrations of Common gulls were recorded at trawlers to the northwest and southeast of Horns Rev, but were also found in areas like the waters off Blåvands Huk and Esperance Bugten (Figure 5-5). The concentrations of Herring gull were more clearly associated with the fishing activities offshore, as were the concentrations of Lesser black-backed gull. Both of these species were recorded in relatively large numbers in association with trawlers near and within the HR2 OWF area. No large flocks were seen within the Horns Rev 1 OWF.

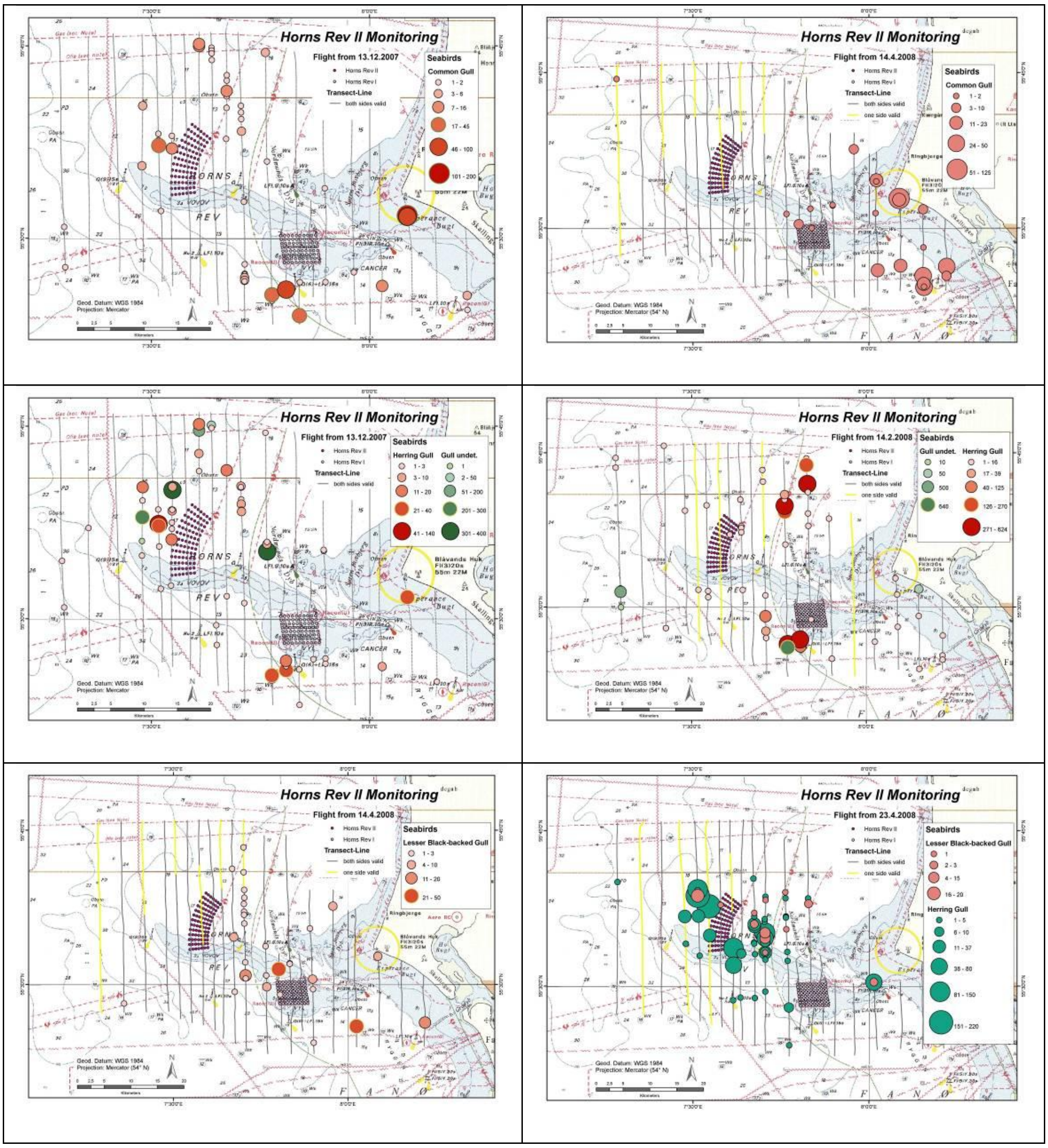

Figure 5-5. Distribution of sightings of Larus-gulls Laridae *from various surveys.*

5.1.4 Kittiwake

Kittiwake *Rissa tridactyla* was seen commonly during all six surveys, and displayed a relatively wide distribution with the largest aggregations in the areas typically frequented by intensive fishing activities to the southeast and the northwest of Horns Rev as well as along the south western slopes and at Cancer where limited commercial fishing activities were going on. The distribution overlapped with the distribution of Razorbill *Alca torda* and Guillemot *Uria aalge* in the western part of the survey area (Figure 5-6). The area of the planned HR2 OWF held medium concentration of kittiwakes, and few birds were seen within the Horns Rev 1 wind farm.

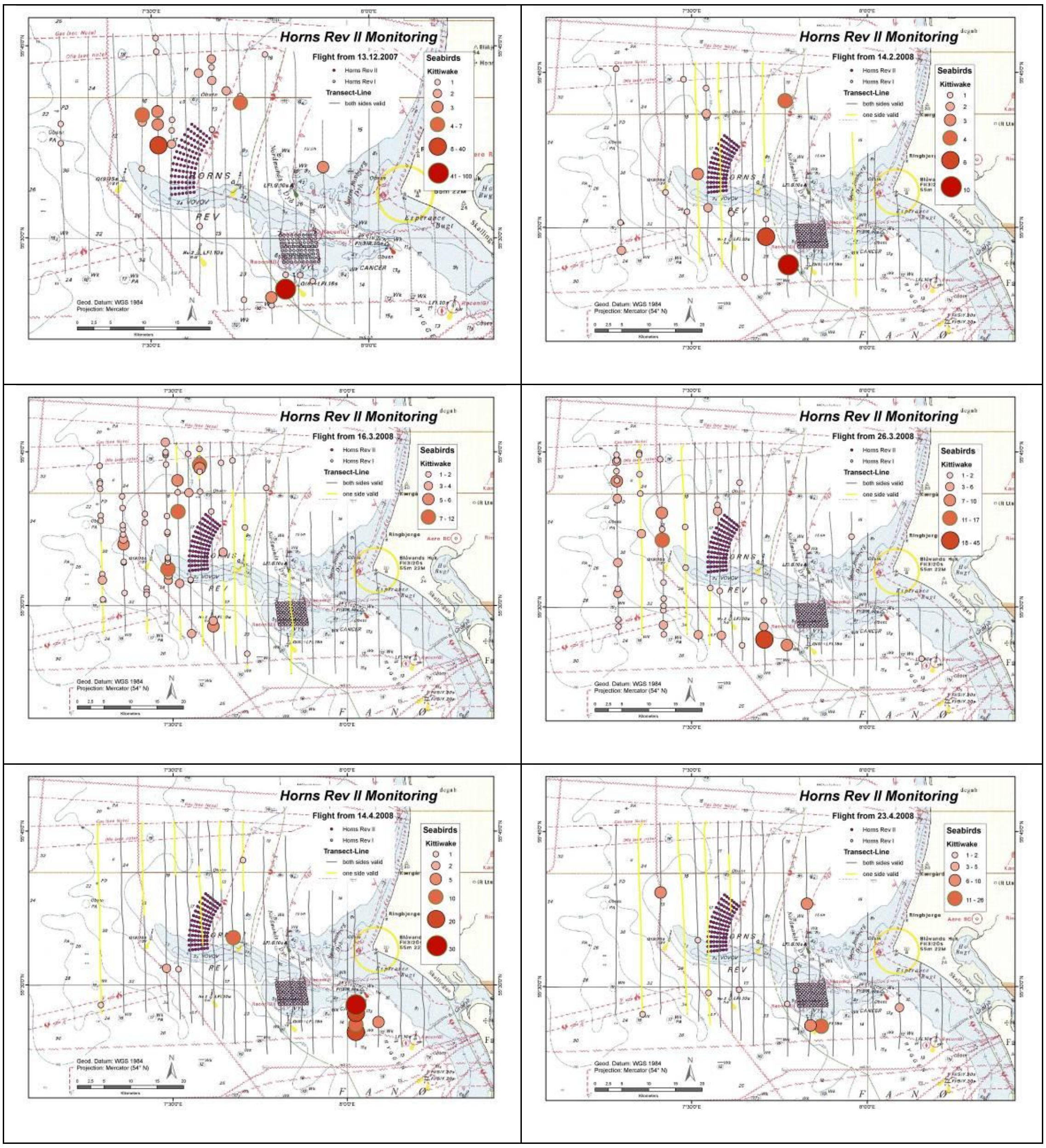

Figure 5-6. Distribution of sightings of Kittiwake Rissa tridactyla *during the six surveys.*

5.1.5 Terns

Both Sandwich terns *Sterna sandvicensis*, Common terns *Sterna hirundo* and Arctic terns *Sterna paradisaea* were observed during their northward migration in late March and April. As feeding behaviour can not easily be distinguished from normal flying behaviour by aerial observation the recorded distribution only gives a slight indication of habitat preferences. The birds seem to use the entire area, with the highest densities west of 8º (Figure 5-7). No major concentrations were recorded. Numbers in the HR2 OWF were small, and no birds were seen within the existing OWF.

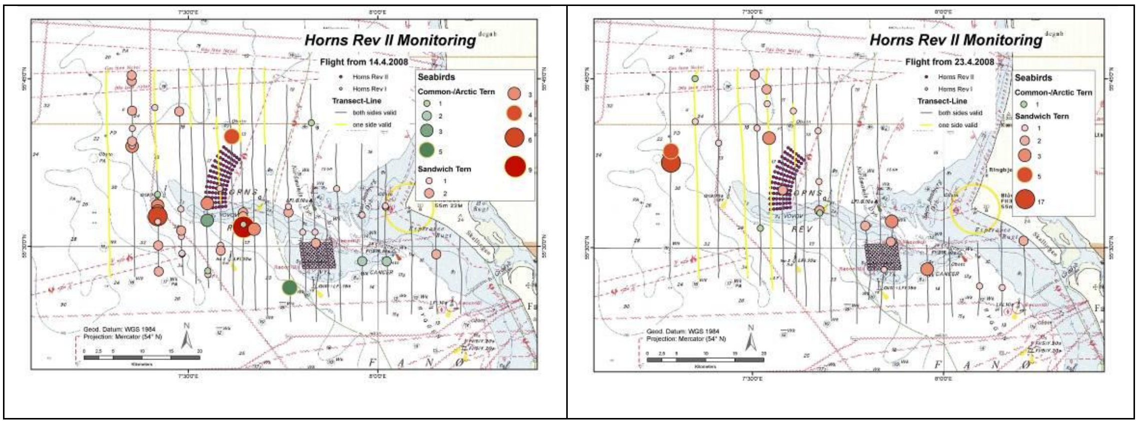

Figure 5-7. Distribution of sightings of Sandwich terns Sterna sandvicensis, *Common terns* Sterna hirundo *and Arctic terns* Sterna paradisaea *during the two surveys in April.*

5.1.6 Razorbill/Guillemot

The auks Razorbill and Guillemot were observed in moderate numbers during the four surveys undertaken during the period December to March. The vast majority of the birds were recorded in the western part of the area west of 7º45’ E. longitude (Figure 5-8). No major concentrations were recorded. Numbers in the HR2 OWF were small, and no birds were seen within the existing OWF.

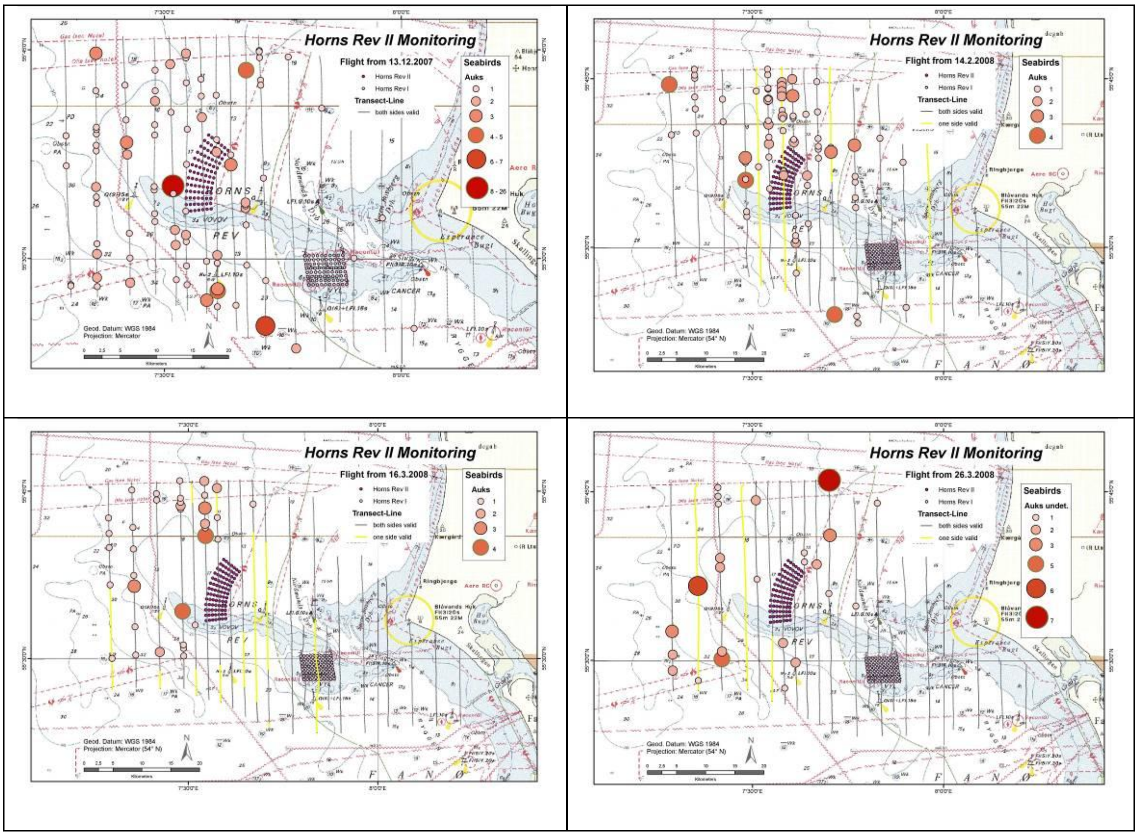

Figure 5-8. Distribution of sightings (lumped data) of Razorbill and Guillemot Alca torda/Uria aalge *during the four surveys during December 2007 – March 2008.*

5.2 Spatial prediction models of Common scoter and Red- /Black-throated diver

The spatial structure of the sampled diver densities indicated the presence of at least two distinct structures marking prominent shifts in the autocorrelation between samples (Figure 5-9). The first shift at the range of 2-4 km coincided with the distance between survey transects, whereas the other at the range of 5-10 km most likely reflected the scale of controlling habitat structures. Accordingly, large scale hydrographic structures in the form of major water mass compartments rather than discrete frontal and upwelling zones were selected as predictor variables along with topographic and landscape parameters.

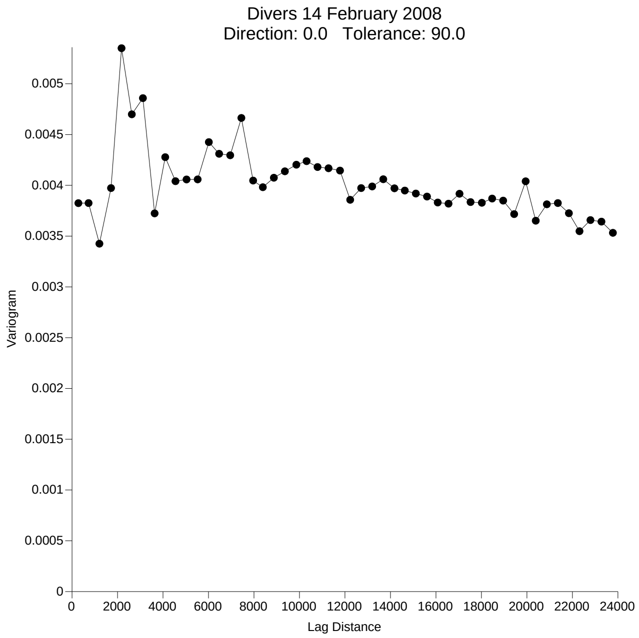

Figure 5-9. Example of autocorrelation structure in density data on Red- and Black-throated diver Gavia stellata/arctica*, here from the survey undertaken 14 February 2008.*

Calculation of autocorrelation coefficients (Moran's I) on the aggregated density samples of indicated that moderate autocorrelation levels (0.416 for divers and 0.194 for Common scoter). The results of the GLM analysis for divers showed that the sampled densities were significantly correlated with the gradient zone between the estuarine water mass and the water mass of mixed North Sea and estuarine water masses from the southern German Bight (negative relationship to the distance to the gradient zone), identified by the mean modelled gradient between 32 and 33 psu salinity (Table 5-3). Correlations were also significant between divers and shallower areas and areas at larger distances from the coast and with interactions between these two parameters and the distance to the estuarine gradient zone.

The resulting spatial GLM model indicated enhanced average densities (> 0.2 birds/km^2) throughout the estuarine gradient zone extending 10-15 km e-w, and areas of higher densities (> 0.2 birds/km^2) over the western sector of Horns Rev, in the HR2 OWF site and over the plains to the north of here (Figure 5-10). The modelled average densities of divers in the HR2 OWF ranged between 0.3 and 0.55 birds/km^2, while densities of divers in the HR1 OWF ranged between 0.05 and 0.2 birds/km^2. The modelled distribution fits well to the observations of divers described earlier, however the predicted density of divers in the inshore zone is too low, as birds were regularly seen here, albeit in low numbers.

Table 5-3. Results of the GLM analysis for Red- and Black-throated diver Gavia stellata/arctica*, showing parameter estimates (PAR), sums of squares (SS), F and p values for the five selected parameters: BATHY (water depth), COMPLEX (complexity of sea floor), SLOPE (slope of sea floor), DIST_LAN (distance to land), DIST_PLUME (distance to 32-33 psu gradient).*

	PAR	SS	F	p
Intercept	0.456069	5.1274	18.84407	0.000016
BATHY	0.028331	12.7653	46.91450	0.000002
COMPLEX	0.178897	0.0731	0.26861	0.604381
SLOPE	-0.012256	0.0002	0.00071	0.978690
DIST_LAN	-0.007809	2.0325	7.46967	0.006386
DIST_PSU	0.037509	1.9600	7.20339	0.007398
DIST_LAN*DIST_PSU	-0.001086	1.5799	5.80621	0.016151
SLOPE*DIST_PSU	0.006342	0.0020	0.00721	0.932326
COMPLEX*DIST_PSU	0.010916	0.0101	0.03708	0.847334
BATHY*DIST_PSU	0.003082	3.0553	11.22874	0.000836

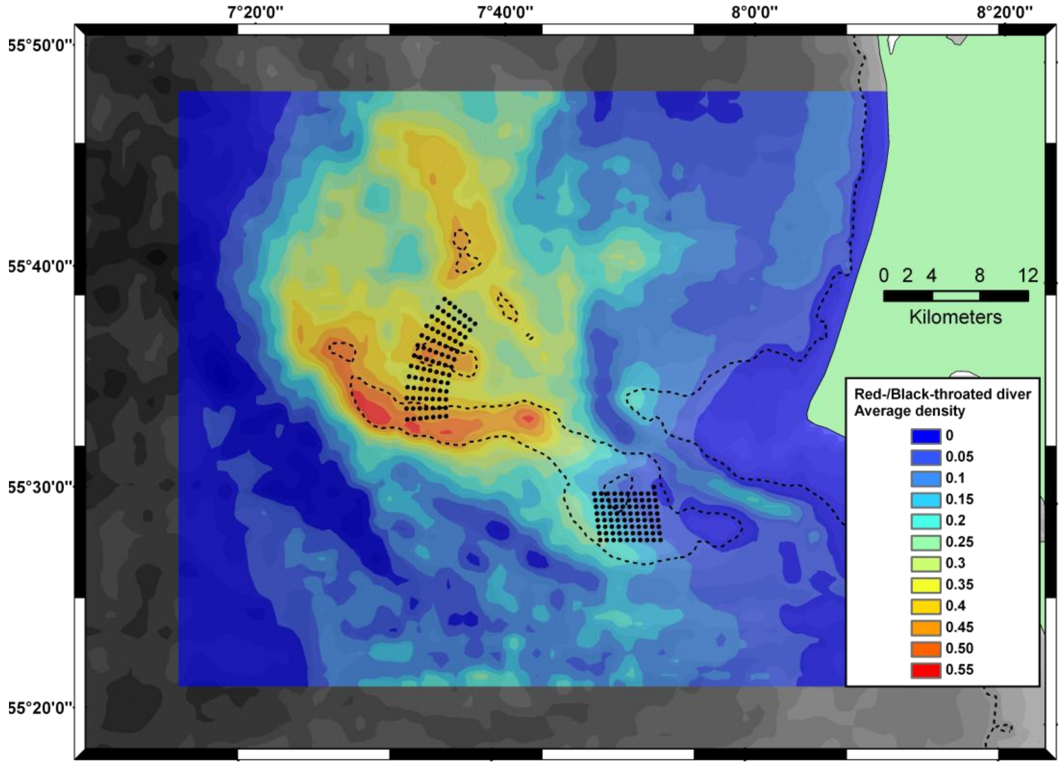

Figure 5-10. The average density (number of birds/km^2) of Red- and Black-throated diver Gavia stellata/arctica *modelled for the six surveys December 2007 – April 2008.*

The results of the GLM analysis for Common scoters showed that the sampled densities for the whole area were significantly correlated with the estimated habitat suitability for *Spisula subtruncata*, with areas close to the coast and areas at longer distances from HR1 OWF (Table 5-4). The estimates of habitat suitability for the two prey species *S. subtruncata* and *E. americanus* were taken from Skov et al. (2008). The resulting spatial

GLM model indicated high densities (> 100 birds/km^2) in the eastern-most part of the modelled area between Cancer and Blåvands Huk, with densities peaking around the 10 m curve off the Danish west coast (Figure 5-11). The model predicted low-medium densities throughout the rest of the model area, with average densities of scoters in the HR2 OWF ranging between 10 and 40 birds/km^2, while densities in the HR1 OWF ranged between 0 and 25 birds/km^2. The modelled distribution fits well to the observations of scoters in the parts of the area dominated by Spisula (the eastern part), while the model predictions are relatively poor in the central and western parts dominated by Ensis due to the lack of overall correlation with Ensis as compared to Spisula.

Table 5-4. Results of the GLM analysis for Common scoter Melanitta nigra*, showing parameter estimates (PAR), sums of squares (SS), F and p values for the five selected parameters: ENSIS (estimated habitat suitability for* Ensis americanus*), SPISULA (estimated habitat suitability for* Spisula subtruncata*), BATHY (water depth), DIST_HR1 (distance to Horns Rev 1 OWF), DIST_LAN (distance to land).*

GLM model predictors	PAR	SS	F	p
Intercept	45.58177	35813	2.70387	0.101200
ENSIS	0.03500	238	0.01794	0.893534
SPISULA	1.13798	100422	7.58188	0.006272
BATHY	-0.17244	116	0.00876	0.925484
DIST_HR1	4.63718	198392	14.97867	0.000135
DIS_LAND	-3.68017	155189	11.71683	0.000710

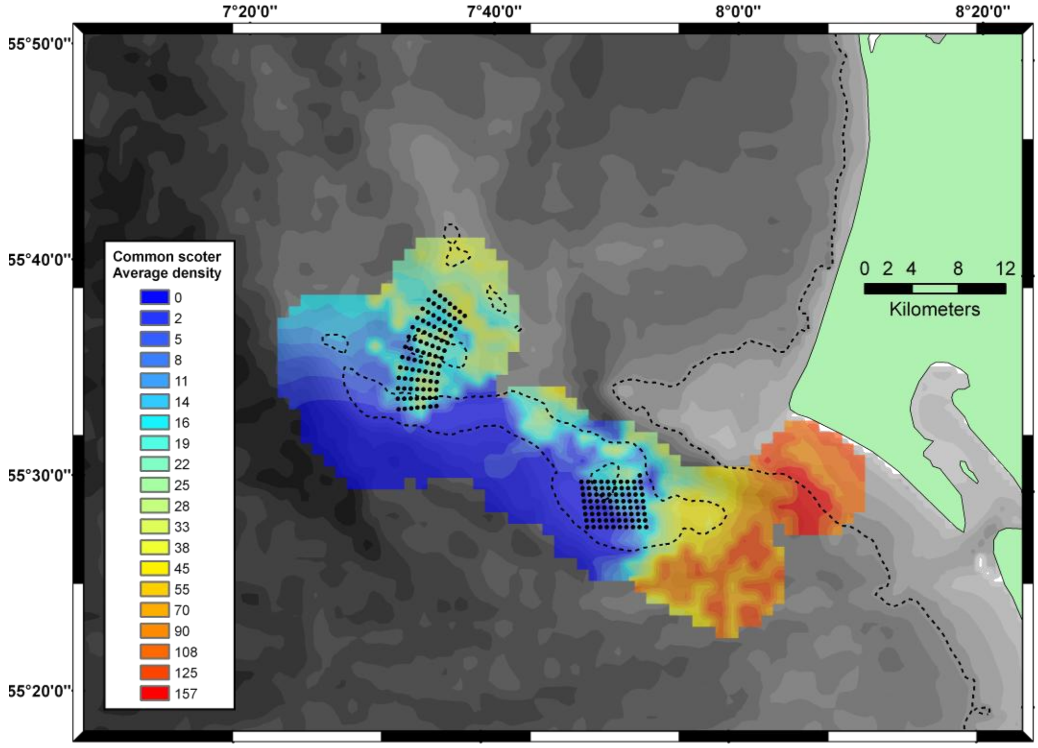

Figure 5-11. The average density (number of birds/km^2) of Common scoter Melanitta nigra *modelled for the six surveys December 2007 – April 2008.*

5.3 BACI design for monitoring programme

A classic BACI design (ANOVA area-time factorial design) will be applied to observations of key species of waterbirds (Common scoter, divers) testing effects of year, treatment (pre-construction and post construction) and block using impact blocks covering the wind farm foot print areas and adjacent impact zones and control blocks. In the Horns Rev 2 monitoring programme it is recommended to design comparisons of before/after construction scenarios based on the spatial models and the habitat suitability models for the two target prey species for scoters using freely chosen areas around the two wind farms. Based on the existing and potentially extended (including PSO data) baseline model grids the impact and control sites can be selected to maximise the use of obtained recordings for the entire Horns Rev area. The model grids will require updated bird survey data and hydrographic and water quality model data. Additionally, the BACI design would benefit from improved and more quantitative background information on the trends in abundance and distribution of the two prey species on Horns Rev.

6 DISCUSSION AND CONCLUSIONS

6.1 Baseline results

6.1.1 Seabird's use of the Horns Rev II area

The variation of the number of birds for the different species recorded within the HR2 OWF as expressed by the six baseline surveys is determined by a combination of the spatio-temporal dynamics of prey and oceanography and the location of the planned wind farm relative to the large-scale distribution of the species.

Comparing the location of the HR2 OWF with the general distribution trends of the target wintering species of waterbirds in the North Sea reveals overlap with the high-density areas of Red-throated/Black/throated divers and partly Common scoter (Skov et al. 1995). The distribution of Common scoter has changed markedly in the eastern North Sea since 2004. Smaller or larger proportions of birds normally located in the area close to Blåvands Huk from time to time, occurring offshore along the central and western parts of Horns Rev (Petersen et al. 2006). These general patterns are well reflected by the results of the baseline with concentrations of divers and to a lesser degree scoters being the most significant results for the planned wind farm site. The distribution of other species displayed more variability between surveys. These findings are corroborated by the survey results from the monitoring programme of Horns Rev 1 (Petersen et al. 2006).

The concentration of Red-throated/Black/throated divers centred along lines around 7 º 30' E longitude at the core of the gradient between estuarine and mixed North Sea water masses represents the most significant monitoring result for the planned wind farm. This result is in line with the survey results from the monitoring programme of Horns Rev 1, although these surveys mainly covered the eastern parts of the study area (Petersen et al. 2006). The result further corroborates existing models of diver distribution in the German Bight depicting long-shore aggregations around the 7º30' E longitude coinciding with the long-term mean position of the estuarine front (Skov & Prins 2001). In Figure 6-1 this is illustrated by the mean gradient zone between estuarine and mixed North Sea water masses modelled during the winter 2007/08 and the location of the modelled high-density area for divers this winter.

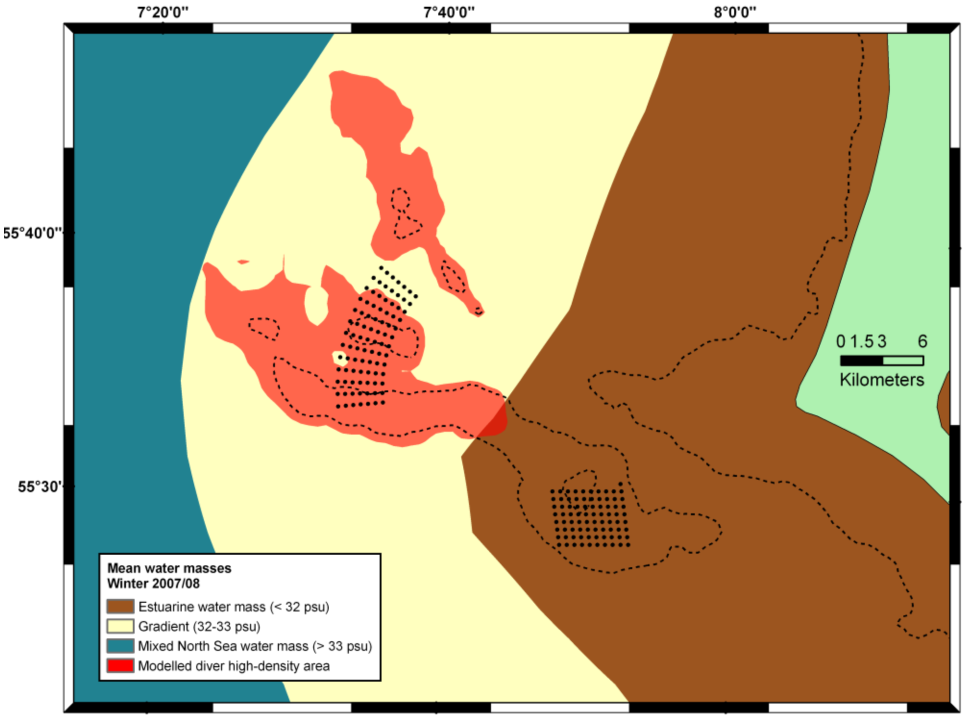

Figure 6-1. The mean gradient zone between estuarine and mixed North Sea water masses modelled during the winter 2007/08 and the location of the modelled high-density area for divers this winter. The latter is defined as the area holding an average density above 0.38 birds per km^2, or equivalent of the mean density +1 SD.

6.2 Monitoring design

The baseline monitoring of resting birds for the HR2 OWF provided useful information which supplement the existing knowledge and data obtained during the PSO monitoring programme, especially in relation to the distribution of Red- and Black-throated divers and Common scoters in the western parts of the Horns Rev area. The survey data collected in combination with dynamic model data on potential food supply and hydrographic conditions are judged as sufficient for the baseline for the HR2 OWF monitoring programme. As the model data cover the entire period from 2000 to present BACI tests may be designed to include some or all of the data collected during the PSO monitoring programme in the baseline.

It should be stressed that both the spatial model for Common scoter and the habitat suitability models for the target prey species *S. subtruncata* and *E. americanus* suffer from a lack of quantitative information, particularly on Ensis and the gradients in the abundance of both species in the Horns Rev area.

6.3 Conclusions

The abundance of most species of waterbirds in the area of the planned HR2 OWF was relatively dynamic with large variations in numbers recorded between surveys. Two species groups, however, seemed to use the area more frequently: Red-throated/Black-throated diver and Common scoter. The distribution of Common scoter has changed markedly in the eastern North Sea since 2004. Smaller or larger proportions of birds normally located in the area close to Blåvands Huk from time to time, occurring offshore along the central and western parts of Horns Rev. These general patterns were also recorded during these surveys with medium concentrations of less than 3,000 birds, or 10% of the total observed in the area, at the shallow ground VovVov located at the southern periphery of the planned wind farm site.

The majority of Common scoters were recorded in the far east of the study area; south of Blåvands Huk in Esperance Bugten, just west of Blåvands Huk and on Cancer on the easternmost tip of Horns Rev. Few birds were seen in the vicinity of the existing OWF, and no birds were seen within the wind farm. In early April the total sample of birds was 11,000, and the birds had left the Esperance area and a larger proportion of the birds or approximately 50% were observed over the central and western parts of Horns Rev as well as in the area to the north of the reef. Only the estimates of average density and abundance of scoters for the survey in early April was of sufficient precision to be used as an indication of numbers present in the whole survey area, and the estimated total was almost 70,000 birds.

Spatial models of the average distribution of Common scoter and divers during the six baseline surveys were developed. The GLM model for scoters indicated that the birds were significantly correlated with the estimated habitat suitability for *Spisula subtruncata*, with areas close to the coast and areas at longer distances from HR1 OWF. The model indicated high densities (> 100 birds/km^2) in the eastern-most part of the modelled area between Cancer and Blåvands Huk, with densities peaking around the 10 m curve off the Danish west coast. The model predicted low-medium densities throughout the rest of the model area, with average densities of scoters in the HR2 OWF ranging between 10 and 40 birds/km^2, while densities in the HR1 OWF ranged between 0 and 25 birds/km^2.

The GLM model for divers indicated that the birds were significantly correlated with the gradient zone between the estuarine water mass and the water mass of mixed North Sea and estuarine water masses from the southern German Bight. The deployment of the model showed enhanced average densities throughout the estuarine gradient zone extending 10-15 km E-W, and areas of higher densities over the western sector of Horns Rev, in the HR2 OWF site and over the plains to the north of here.

The survey data collected in combination with dynamic model data on potential food supply and hydrographic conditions are judged as sufficient for the baseline for the HR2 OWF monitoring programme. As the model data cover the entire period from 2000 to present BACI tests may be designed to include some or all of the data collected during the PSO monitoring programme in the baseline.

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A P P E N D I C E S

A P P E N D I X   A

List of bird observations

			2007	2008				
Species	**scientific name**	**Sum**	**Dezember 13th**	**February 14th**	**March 16th**	**March 26th**	**April 14th**	**April 23rd**
Diver sp.	*Gaviidae* indet.	462	65	77	45	84	129	62
Fulmar	*Fulmarus glacialis*	38	5	17		8	1	7
Gannet	*Sula bassana*	23	1	1	7	10	2	2
Tufted Duck	*Aythya fuligula*	2						2
Eider	*Somateria mollissima*	311	73	115	103		20	
Common Scoter	*Melanitta nigra*	120,179	39,577	17,174	26,253	25,265	11,059	851
Velvet Scoter	*Melanitta fusca*	132		4	5	48	26	49
Great Skua	*Stercorarius skua*	1					1	
Little Gull	*Larus minutus*	75					23	52
Black-headed Gull	*Larus ridibundus*	123	5	109	1	5		3
Common Gull	*Larus canus*	3,163	398	2.073	23	29	398	242
Lesser Black-backed Gull	*Larus fuscus*	407	14		121	8	203	61
Herring Gull	*Larus argentatus*	6,668	449	3,094	1,146	231	413	1,335
Great Black-backed Gull	*Larus marinus*	25		5	5	12	3	
Kittiwake	*Rissa tridactyla*	710	198	40	141	164	100	67
Gull sp.	*Laridae* indet.	3,813	1,551	1,214	403	247	0	398
Sandwich Tern	*Sterna sandvicensis*	138					82	56
Arctic/Common Tern	*Sterna hirundo / paradisaea*	19					16	3
Razorbill/Guillemot	*Alca torda / Uria aalge*	377	155	108	50	54	7	3
Little Auk	*Alle alle*	1	1					
Harbour Porpoise	*Phocoena phocoena*	188	29	31	22	36	50	20
Seal sp.	*Pinnipedia indet.*	15	3			3	4	5
Harbour Seal	*Phoca vitulina*	34	3	6	1	2	11	11